D E C E M B E R 1 9 9 0

THIS ISSUE

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Flip the Flap →

As I was saying—

MERRY CHRISTMAS to all of you from all of us!

There are 20,142 of you and there are 34 on the staff, so that makes 684,828 good-will messages on this page. The power of the printed word is surely great!

Right after Thanksgiving we start using the Christmas stationery. It has the holly leaves and berries on the lower left-hand corner and really we all find it a great pleasure to sign the mail in the Spirit of the Season. When the was young and had few members the Society sent Christmas cards to all of them, but the custom was discontinued as it seemed like sending greetings to themselves. The Past-Presidents and present members of the Board of Trustees still rate a Christmas reminder of something from the farm, either a side of hickory-smoked bacon or — if the sugar bush is productive — a can of Sunnimoor maple syrup. (Each recipient supplies his own pancakes!)

The year 1950 has been a wonderful one for your Society. The regular services have been continued and improved. *Metal Progress* has increased its editorial staff as well as its scope (still *the* engineering magazine of the metals industry); *Transactions* has increased the number and quality of its articles; *Metals Review* has not only kept you informed of chapter doings but told you about ten thousand articles on your favorite subject that were published in four hundred journals the world over; the "Metals Handbook", with a distribution of 27,258 copies, has yet to receive a letter of criticism either about the text or the index; the 32nd Congress and Exposition held in Chicago in October proved to be a grand success.

There were other services like books, preprints, employment, chapter meetings, educational courses, aids to teaching and many others which if I remarked upon, deservedly, you might think I was "bragging" about the — Well, am I? And there's one nice thing about this whole picture and that is that the members' dues have remained the same since the organization of the Society. Truly: The Engineering Society of the Metals Industry.

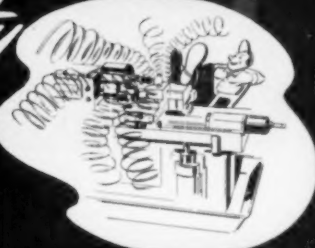
So at this Season we all have much for which to be thankful — our family, friends, health, jobs — and added to these personal factors, a satisfaction in knowing that we are joining with others in the upbuilding of the profession to which we belong.

So, let's have a Merry Christmas!

Cordially,

Bill

W. H. Eisenman, Secretary
American Society for Metals



Major Advance in Electric Control Increases Production From Industrial Operations

With production demands reaching toward fresh all-time highs, this new P.A.T.'50 Control comes at the ideal time to help thousands of firms increase the output of their industrial furnaces. Here's why:

This Control has something that's brand new. It acts on the *speed* of swings in furnace load, as well as on their size and permanence. Thus, if temperature changes gently, it is gently nudged back into line. But if it starts off briskly—as when the furnace door is opened—P.A.T.'50 reacts briskly. The faster the change, the further P.A.T.'50 moves the fuel valve. Then, at the instant this action begins to head off the change, the Control starts backing away. By putting on the brakes it brings temperature back in line smoothly, rapidly.

This "Rate Action" increases production because it reduces the length of time a furnace is off temperature. It means more heats per week.

P.A.T.'50 is the Only electric positioning control with Rate Action. It's a unique L&N contribution to automatic regulation.

Also, Proportioning and Reset Actions are more responsive than before. These two components have always been vital to automatic control, and of course continue so. They stop the normal, every-day temperature swings which are started by changes in the size and permanence of the furnace load.

When we gave P.A.T. its third component of rate action—and introduced it in this '50 model—we were able also to increase the sensitivity and range of adjustment of proportioning and reset components. The resulting improvement in control action shows up at all times, but especially when temperature is being stubborn—trying to edge away from the control point, or to level off incorrectly. Even without rate action, P.A.T.'50 would do a better-than-ever job. But with rate action, results are far superior to any previous electric control.

The News is in the Control Unit. Everything new in P.A.T.'50 is in the Control Unit—the device in center of above illustration which is usually mounted below the Speedomax or Micromax Recording Controller, and which links that instrument to the fuel-valve-driving mechanism. In line with our policy of making improvements readily available to users of our equipment, earlier installations of P.A.T. Control can be converted to P.A.T.'50 by replacing the Unit and making slight changes in the Controller. The new Unit is fully electronic—has no moving parts except two hermetically-sealed relays.

For complete details, contact our nearest office, or write us at 4927 Stenton Ave., Philadelphia 44, Pa.

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

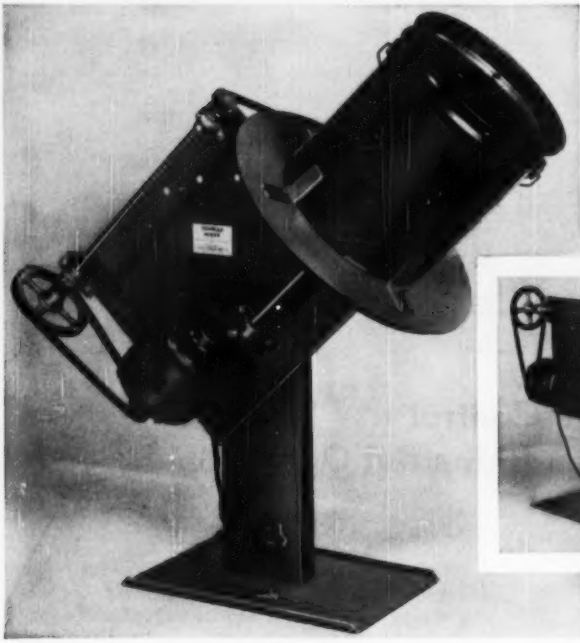
LEEDS & NORTHRUP CO.

Jrl. Ad ND4-33(1)

Metal Progress is published and copyrighted, 1950, by American Society for Metals, 7301 Euclid Avenue, Cleveland, Ohio. Issued monthly; subscriptions $7.50 a year. Entered as second-class matter Feb. 7, 1921, at the post office at Cleveland, Ohio, under the act of March 3, 1879.

Tumble solids or mix liquids in almost any container with

The new Rampe Tumbler-Mixer



★
Tilts thru 90 degrees
★
Anti-friction bearings
★
Saves time, space, expense
★
Portable for easy moving
★

Tumble or mix many things with the Rampe Universal Portable Tumbler-Mixer. This low-cost, space-saving machine tilts in a full 90-degree arc so that you can tumble your work at the proper angle for best results. It enables you to keep your tumbling near your work, saving time and unnecessary transportation.

Its adaptability is due to the adjustable turntable clamps that strongly grip standard and oddly shaped containers. The clamps easily hold a five-gallon pail, wooden box, can, jug, stone jar, laboratory beaker, or containers of most any other shape that you may have in your laboratory. Small shops, experimental departments, chemical plants, laboratories will find the Rampe Tumbler-Mixer ideal for their purposes.

SPECIFICATIONS:

Anti-friction bearings used throughout, for long life.

Special automatic slack take up provided to keep turntable belt tight.

Turntable size, 19 inches outside diameter.

Motor—1/6 H.P., 110-volt, AC single phase; 8-foot cord and plug. Start-stop switch.

Floor space required—32″ x 19″.

Height from floor when fully raised, 35″.

Weight, 80 pounds.

Finish, gray.

H-51610—Rampe Universal Portable Tumbler-Mixer, Each **$99.50**

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DIVISION OF THE HARSHAW CHEMICAL CO.
CLEVELAND 6, OHIO

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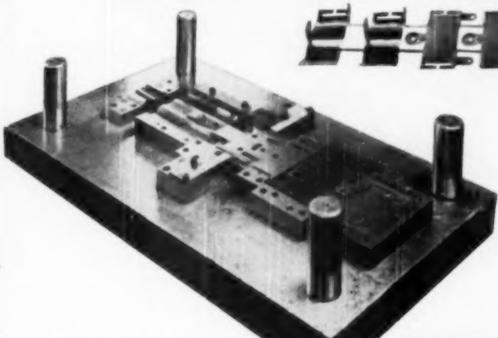
Tool Steel Topics

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

LEHIGH H PRODUCES 20,000 PARTS DAILY FOR VENETIAN BLINDS



This seven-stage progressive die is made entirely of Lehigh H. It blanks, embosses, and forms venetian blind parts from .032-in. cold-rolled steel. Hardened to Rockwell C-61, it produces about 20,000 pieces daily.

Photo courtesy: A. F. & G. Tool & Die Co., Inc., Baltimore, Md.

This popular high-carbon, high-chromium steel wears . . . and wears . . . and wears.

It's air-hardening, of course. Veteran toolmakers like the way it holds the closest dimensions during heat-treatment. It's deep-hardening, too; and has high compressive strength. If there ever was a tool steel made for maximum production, it's Lehigh H!

Detective Work Needed When Dies Fail

Dies that are made from the right tool steel and properly heat-treated will stand a lot of abuse. But there are limits. Just the other day, for example, we saw a broken die made from a reliable grade of tool steel. It was made for blanking pieces from 18-gage sheet steel, and the clearances were carefully designed accordingly.

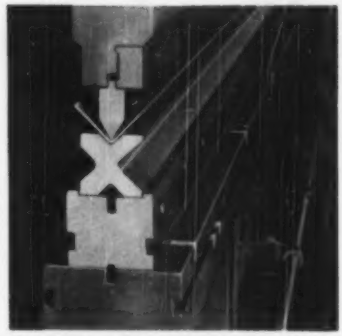
When the die was delivered to the shop, an over-anxious operator couldn't wait to try it out. His sheet steel wasn't available, but he found a pile of light steel plate and started banging out sample pieces. Result: a broken die.

In a case like this, the first impulse is to point an accusing finger at the tool steel. Experience shows, however, that the fault nearly always lies in the design, heat-treatment, grinding, or in the use of the tool or die.

Fresh water is all right for chasers, but don't use it for quenching tools.

Fresh water, regardless of its source, contains dissolved gases which make it unsuitable for the quenching of tools. When tools are quenched in fresh water, gas is liberated at the surface of the tool. Gas pockets thus formed may prevent contact between tool and water to an extent that soft spots are produced as a result of ineffective quenching. Soft spots are undesirable, not only because of their low hardness, but because a quench which produces soft spots is also likely to cause cracking of the tools.

Soft spots, and tool cracking associated with soft spots, can be avoided by quenching in water which has been boiled to remove dissolved gases. If the water cannot be boiled, quench a large amount of hot "dummy" material to expel the gases. It is preferable to use a 10 pct brine solution instead of water as a further precaution against soft spots. Care should also be taken to expel dissolved gases from the brine solution before use.



Typical brake die assembled in a press brake. Bethlehem Brake Die Steel is heat-treated, ready to use, needs no further hardening. It gives long wear, has high tensile strength and plenty of shock-resistance.

Sheet-Metal Brakes Call for Special Brake-Die Steel

Among those people who have sheet-metal brakes in their shops are a few who are accustomed to using just any old steel for their brake dies. They find that they can get a cheap steel to use for this purpose and they see no reason for paying a higher price.

In the long run, these folks will pay a fancy price for the "cheap" steel by the time they get through fussing around with it, doctoring up the ordinary steel to take out the twists and bends. Shop overhead and costs run high these days.

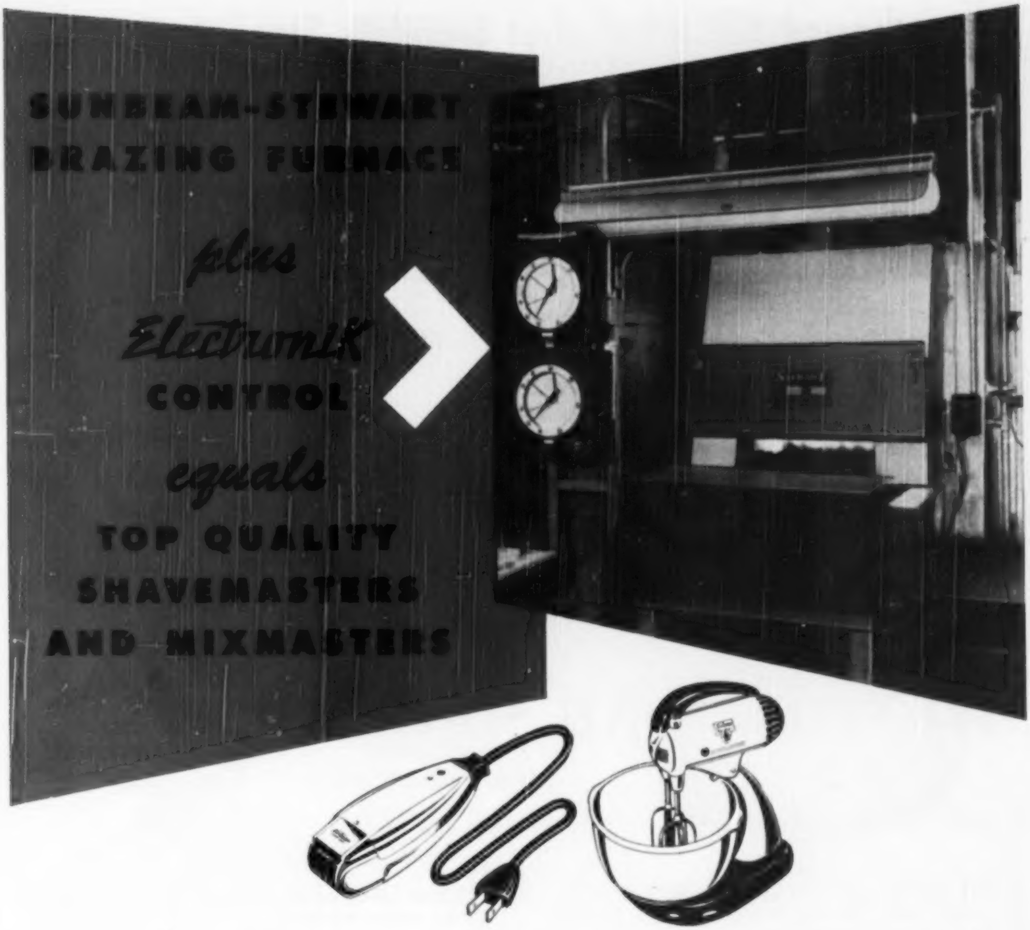
Bethlehem Brake Die Steel is really tops for its special-purpose job.

We stock this steel in standard sizes in our Mill Depot. It's carefully heat-treated, oil-quenched and tempered, then straightened and stress-relief annealed to prevent warping when it's machined by the die-maker. It's engineered to machine easily and to give long wear in service.

The maker of brake dies can machine this fine steel to accurate contour and not have to worry about whether or not it's going to *stay* straight. It's economical to make up into dies because it's heat-treated, ready for use without any further hardening.

Like to know more about it? Write for Folder 560, addressing our nearest sales office or our Publications Department at Bethlehem, Pa.

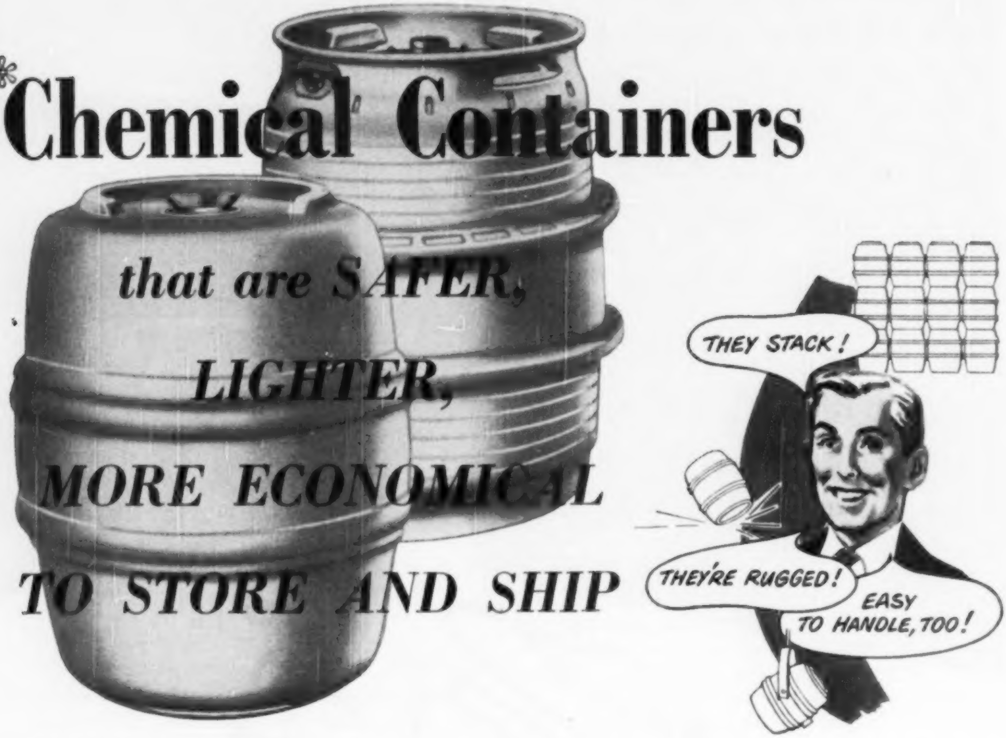
Bethlehem ULTRASONIC TESTED **Tool Steel**


SUNBEAM-STEWART
BRAZING FURNACE
plus
ElectroniK
CONTROL
equals
TOP QUALITY
SHAVEMASTERS
AND MIXMASTERS

Another of the Jobs* that Stainless Steel does BEST

*Chemical Containers

that are SAFER, LIGHTER, MORE ECONOMICAL TO STORE AND SHIP



FOR YEARS and years, commercial acids and other "bad" chemicals were shipped in glass carboys protected up to the neck by unwieldy wooden crates. At very first glance, you will see how these modern stainless steel chemical containers were vast improvements in strength, safety and ease of handling, but there were other important advantages.

For one thing, each stainless drum holds 25% more acid by volume than a carboy, yet weighs some 10% less when filled. The saving in freight rates alone, every time the drum is shipped and returned, is more than 30%. In addition, the stainless container is designed to self-stack, solidly and securely. A two-high stack of drums, compared to unstacked carboys, gives you about three times as much gallonage per square foot of floor space in a freight car, truck bed or warehouse.

Like so many other applications for Allegheny Metal, therefore, these chemical containers are important to the national economy. Stainless steel is a vital material, both in essential industrial uses and in the building of armament. ● Let us help you to use it wisely and well, to get the least possible wastage per ton. *Our engineers are at your service.*

* * * *

Complete technical and fabricating data—engineering help, too—are yours for the asking from Allegheny Ludlum Steel Corporation, Pittsburgh, Pa. . . . the nation's leading producer of stainless steel in all forms. Branch Offices are located in principal cities, coast to coast, and Warehouse Stocks of Allegheny Stainless Steel are carried by all Joseph T. Ryerson & Son, Inc. plants.

W&D 3264

You can make it BETTER with

Allegheny Metal

AL TIME-TESTED STAINLESS STEEL

HERE'S HOW...

TO PLAN YOUR
TOOLROOM HEAT TREATING DEPARTMENT

Published to assist those planning new or expanded heat treating departments. It's yours for the asking.

Material contained in this 24 page booklet, prepared by the Lindberg Engineering Company, is based upon years of experience in helping design hundreds of toolrooms . . . plus additional information gained from the 24-hour-a-day operating experiences of the toolroom heat treating department of the Lindberg Steel Treating Company, the world's largest.

It helps arrive at total costs in advance • Shows recommended department layouts • Tells how to select furnaces of proper size • Gives prices of auxiliary equipment such as tongs, quench tanks, straightening presses, hardness testers, work benches, etc. • Contains loose template pages of furnaces, quench tanks, etc. and graph paper . . . a few seconds of scissor work shows you how your department will look.

To get your copy write or call your nearest Lindberg Engineering Company office or the Lindberg home office at 2448 West Hubbard Street, Chicago 12, Illinois.

Other helps for Heat Treaters. "Heat Treating Hints"—a publication covering the practical side of heat treating with strictly "how to do it" articles. Available on request.

"Heat Treating Hints", two movies, (color and sound) bring to the screen practical articles from the printed "Heat Treating Hints". Ideal for technical associations, plant showings, schools. Write for Bookings.

LINDBERG FURNACES

Tests show New Quench Oil has Intensified Triple Action

● A new accelerated quenching oil has been developed that gives (1) rapid heat removal with faster cooling rate in the hardening range, this results in higher and deeper hardness; (2) slow cooling below the hardening range, thus minimizing distortion; (3) greater stability due to special anti-oxidants, for longer life and bright quenching properties.

To better illustrate the manner in which this triple action quenching oil accomplishes this higher quenching efficiency, it will be well to show the three stages of cooling as observed when steel is quenched in oil from a red heat. These stages are:

A. Formation of a vapor film at the steel surface; cooling is accomplished by conduction and radiation through this vapor film and is relatively slow.

B. Direct contact of the oil with the metal surfaces, causing a boiling action which continually dissipates the vapor film formed and results in rapid cooling.

C. After the metal has been cooled to the boiling point of oil, vapor is no longer formed; cooling is by conduction and convection, and the metal slowly cools to the temperature of the oil.

It is apparent that any improvement in the cooling power of oil in stages A and B would be most desirable. This can be compared to the brine quench which is used instead of water. Brine has a wetting action that completes the quench faster than fresh water, which "takes hold" only in spots, causing non-uniformity. Salt brine solutions provide deeper and more uniform hardnesses. This results in deeper and more even hardnesses. It seems logical to attempt to do this same thing with oil. The mineral intensifiers added to this Triple A Quenching Oil act in this manner.

Practical Application of Quench Curves to Hardening Steel

The improvement of oils so as to effect this desired change in the cooling characteristics has been attempted in the past by blending mineral oil with animal oils, but the product was prone to become rancid, or to decompose on contact with hot steel. These blends were also unsatisfactory as quenching mediums for steel treated in certain types of salt baths.

Developed in the Research Laboratory of the Park Chemical Co., the Park Triple A Quench Oil, a blend of specially refined mineral oils, cools steel faster in the upper temperature range by shortening the duration of vapor stage (A) and intensifying the action of boiling stage (B). Heat removal in stage (C) is slow and uniform. Thus, the best surface hardness and depth of hardness penetration are achieved with no danger of cracking or distortion.

Extremely stable, this new accelerated quenching oil may be used as a quench from any heat treating medium without fear of rancidity, oil breakdown, or change in quenching efficiency. Further, Park Triple A Oil is especially suitable for obtaining the maximum uniform oil-quenched hardenability from low and medium alloy steels.

Results of the improvement are shown in chart below showing actual hardnesses in quenched pieces. There is a 16% surface hardness increase with Park Triple A Oil over a good grade of straight mineral oil. The effect would be greater when comparing it with some of the poorer grades of oil used for quenching. Center hardnesses of the one-inch diameter piece are up 14%. Lighter sections would show even more increases.

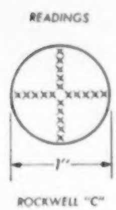
Bright Quenching and Stability

A very crucial and costly problem in the carbo-nitriding process has been the cleanliness of work after oil quenching. Oils which deteriorate rapidly or were originally unsuitable leave a sooty carbonaceous film on the surface of the work. This presents a difficult cleaning problem when followed by a plating or welding operation.

This difficulty, when not the fault of the furnace atmosphere, can be corrected by the use of Park Triple A Quench Oil.

Through the use of anti-oxidant additives and mineral intensifier it has been possible to prolong the bright quenching properties of good clean oil. Underwood Oxidation experiments have proven Park Triple A Quench Oil to have exceptional stability and long life.

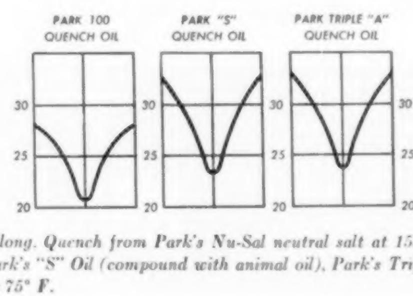
A Bulletin, #F8, was prepared on Park's Triple A Quench Oil. It gives you a complete description of this oil with cooling curves, production data and photographs. Write Park Chemical Co., 8074 Military Ave., Detroit 4, Mich.



STEEL: S.A.E. 1045 1" ϕ x 2"

TREATMENT: 1550° F. IN NEUTRAL SALT QUENCH IN OIL AT 75° F.

HARDNESS: ROCKWELL "C" READINGS ACROSS INNER SURFACES OF SECTIONED SAMPLES



Transverse hardness Rc taken on 1" round SAE 1045 steel two inches long. Quench from Park's Nu-Sal neutral salt at 1550°F. into three types of quench oil, Park's No. 100 Oil (straight paraffin), Park's "S" Oil (compound with animal oil), Park's Triple A Oil. Oil temperatures 75° F.

"Competitive in price . . . *superior in quality*"

These are the basic considerations that influenced Ware Laboratories, Inc., in standardizing on Alcoa Aluminum Fasteners for their line of aluminum windows, doors, and fenestration materials.

Says Bob Olson, Ware V.P. in Charge of Sales...

". . . . to maintain this high quality, Ware's top management and engineers agreed that where aluminum fasteners are used, they must be of the highest quality from the standpoint of appearance and function. In every instance, Alcoa Aluminum Fasteners are selected to do the job. Please accept our congratulations on a highly functional, competitively priced, superior product."

Alcoa fasteners can do a better job for you, too. So, if you make an aluminum product, remember—it's smart business to fasten it with Alcoa Aluminum Fasteners. Write to: ALUMINUM COMPANY OF AMERICA, 2135M Gulf Building, Pittsburgh 19, Pennsylvania.

THE LOWEST-COST CORROSION-RESISTANT FASTENERS ARE

ALCOA *Aluminum* FASTENERS


stainless mouldings
• are everbright • can't peel or discolor • are solid, strong and tough!
stainless mouldings fabricate better, deliver maximum consumer benefit, when you choose and use precision-made
Superior STAINLESS STRIP STEEL
Because SUPERIOR Stainless Strip Steel handles more easily in mouldings manufacture, you enjoy an extra advantage . . . and easier handling is a built-in factor because we have the specialist's *know-how.* We produce only strip steels . . . to strictly-maintained standards of quality and precision in every grade, temper, dimension and finish . . . SUPERIOR through and through!
Superior Steel
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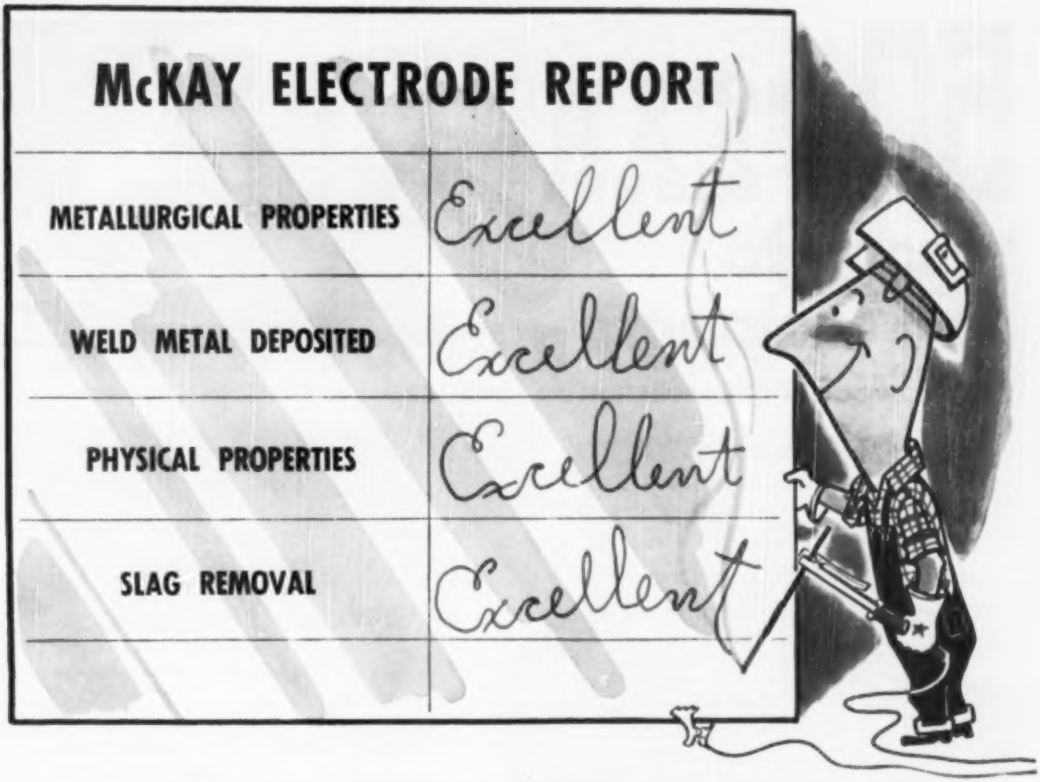


The Case of the Right Report

A perfect rating every time—all the time . . . that's the performance record of every McKay Electrode. Experienced welding men know that uniform Electrodes, with fully controlled properties, are a "must" for structurally sound weldments.

McKay Electrodes are formulated to provide metallurgically sound weld-metal with specific physical properties. Absolute control in each manufacturing operation assures uniformity in every Electrode in the McKay line.

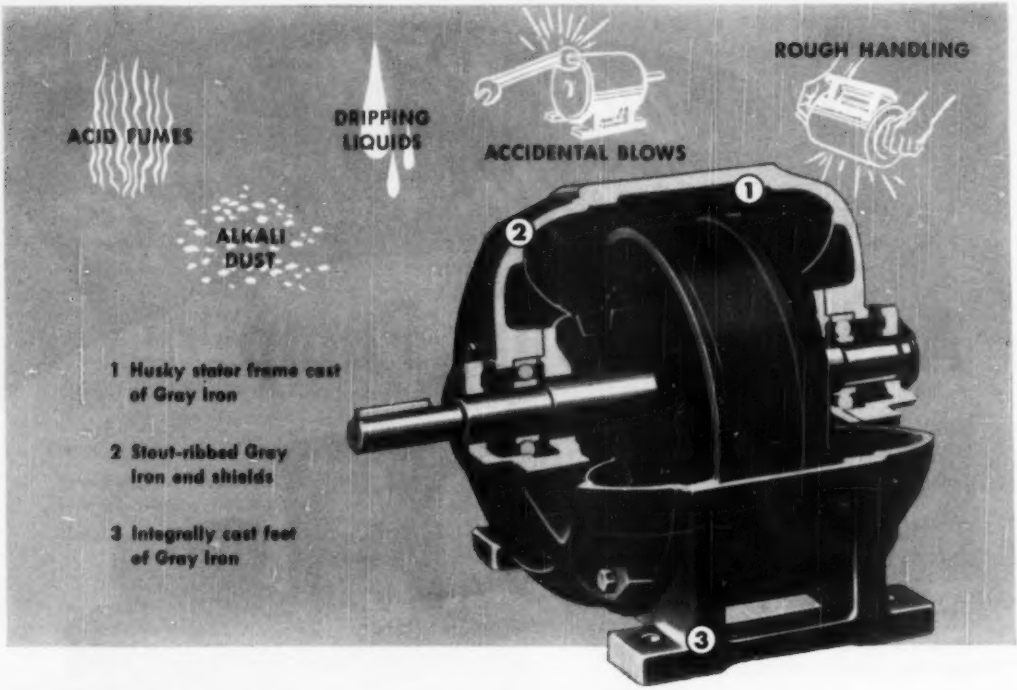
* * * * * *

Our Technical Staff will appreciate the opportunity to recommend the Electrodes best suited for your particular needs and send you samples for "on-the-job" tests.

McKAY
ARC-WELDING
ELECTRODES
For MILD, STAINLESS & ALLOY STEELS

HAVE YOU HEARD ABOUT THE NEW McKAY 16 (AWS E-6020) ELECTRODES?

THE McKAY COMPANY
403 McKAY BUILDING
Pittsburgh 22, Pa.



Where motors get ROUGH USE GRAY IRON can take it!


Typical motor end plates cast of Gray Iron

Leading motor manufacturers use Gray Iron for the following important reasons:

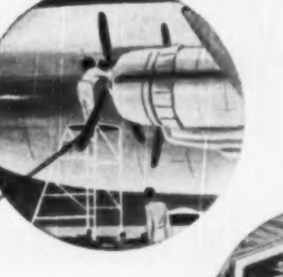
- Damping action that minimizes noise and vibration.
- Rigidity which insures permanent shaft alignment.
- Extra protection against jarring blows and rough handling.
- Resistance to rust and corrosion.

Why not take a tip from leading manufacturers and specify Gray Iron where your product must stand up under rough usage? Whether it's corrosion, abrasion, heat or vibration . . . Gray Iron can take it!

Make It Better with Gray Iron . . . Second largest industry in the metal-working field.

GRAY IRON FOUNDERS' SOCIETY, INC.
NATIONAL CITY-E. 6th BLDG., CLEVELAND 14, OHIO

For Military and Heavy Duty Civilian Requirements



SOLVE ALLOY PLATING PROBLEMS

with B&A Lead and Tin Fluoborate Solutions

Baker & Adamson Metal Fluoborates Offer You These 9 Big Advantages:

1. No mixing or dissolving necessary . . . supplied in concentrated solution form
2. Easier bath preparation
3. Stability of bath composition
4. Ease of control
5. Practically 100% anode and cathode efficiency
6. High conductivity
7. Good covering power
8. Fine-grained deposits of good color
9. Faster, high-speed operation

WHEN COMBINED IN BATHS using alloy anodes, B&A Lead and Tin Fluoborate Solutions plate out dense, fine-grained lead-tin deposits . . . uniformly . . . simultaneously! Thus in one operation an alloy coating is produced that is harder, more wear-resistant than lead plate alone . . . *the answer to plating airplane and automotive bearings that undergo terrific punishment!*

EQUALLY IMPORTANT FOR MILITARY and civilian needs is their use in producing coatings of excellent solderability on radio or electrical parts where the use of a non-corrosive flux is desirable. The fluoborate electrolyte produces an even, fine-grained coating . . . and is faster . . . more economical than hot dipping. Storage tests have shown that parts plated with lead-tin alloy retained this excellent solderability characteristic, whereas other coatings are adversely affected.

FOR WORKING SAMPLES of Lead, Tin, Copper, Zinc, and Nickel Fluoborates—and for sound, practical information on their application—contact your nearest General Chemical Office or write Baker & Adamson Products, General Chemical Division, 40 Rector St., New York 6, N. Y.

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* Complete stocks are carried here.

Announcing... U·S·S

A NEW HEAT-TREATED ALLOY STEEL WITH

MECHANICAL PROPERTIES—U·S·S Carilloy T-1 Steel can be furnished Heat Treated to the following mechanical properties:

	Thickness ¼" to 2" incl.	Thickness Over 2" to 4" incl.	Thickness Over 4" to 6" incl.
Yield Strength, 2% Offset (min.)	100,000 psi	90,000 psi	90,000 psi
Tensile Strength (min.)	115,000 psi	105,000 psi	105,000 psi
Elongation in 2", % (min.)	18	17	16
Reduction of Area, % (min.)	55	50	45

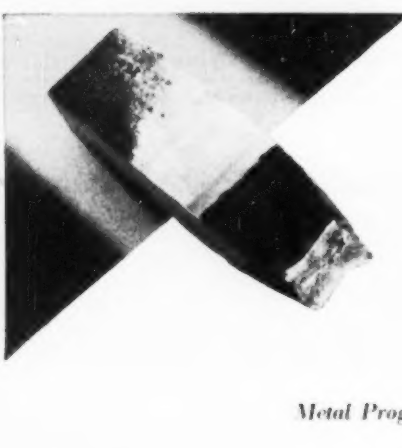
	Thickness ¼" to ½" incl.	Thickness Over ½" to 1" incl.	Thickness Over 1" to 2" incl.
Cold Bend	180°D=1t	180°D=2t	180°D=3t

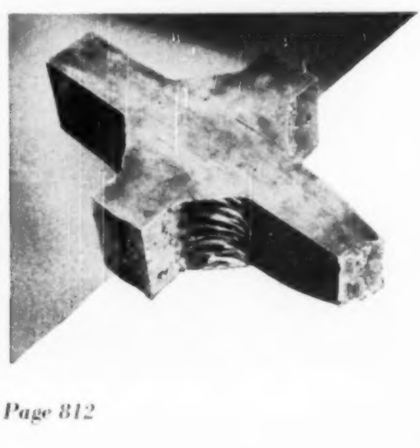
(Testing in accord with A.S.T.M. recommended practices.)

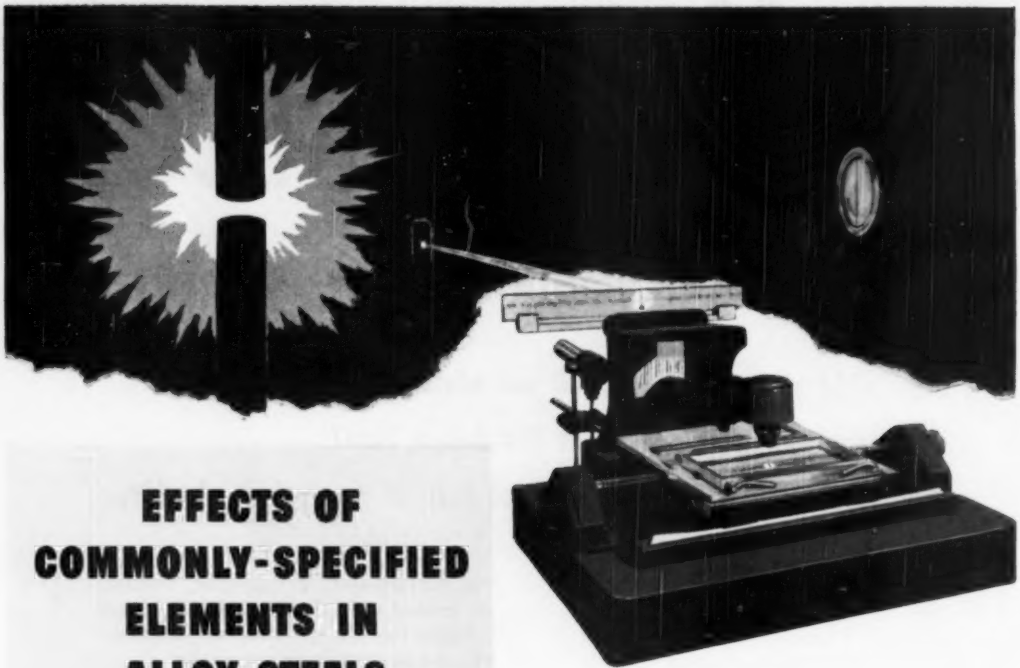
Look at these test results:

90° at 98 below! The sample here was flame-cut from 1" plate. Then it was chilled to -98°F, and bent to a full 90° angle. Even though the raw, flame-cut edge made up the outer radius of the bend, there was no sign of failure!

100% WELD STRENGTH—Tensile tests on welded specimens like these prove that welds on CARILLOY T-STEEL are 100% efficient. Welds develop the *full* strength of the parent metal. Note that breaks occur outside the heat-affected zone. No special pre-heating or post-heating treatments are required beyond those used with ordinary structural steels.







EFFECTS OF COMMONLY-SPECIFIED ELEMENTS IN ALLOY STEELS

The effect of a combination of alloying elements on the properties of an alloy steel is considerably greater than the sum of the effects of these elements if used separately. This inter-relation must be taken into account whenever a change in a specified analysis or composition is evaluated. To simplify the subject we have outlined below some of the individual effects of four of the leading elements used in alloy steels.

NICKEL—One of the fundamental alloying elements, nickel provides steel with such advantages as improved toughness at low temperatures, low distortion in quenching, good resistance to corrosion, and ready response to economical methods of heat-treating. Nickel steels are suitable for case hardening and have excellent resistance to impact, wear and fatigue.

CHROMIUM is an element used primarily to increase the depth-hardenability of steel. It also promotes carburization and improves resistance to abrasion and wear. Used in quantities of over 4.00 pct, it adds considerably to corrosion-resistance. High-chromium steels have relatively good air-hardening properties.

MOLYBDENUM—This element, which does not readily oxidize, provides a large measure of hardenability to steel and is particularly useful where close control of hardenability is required. It greatly increases the high-temperature strength as well as the creep strength. It also provides resistance to many forms of corrosion, and reduces temper brittleness.

VANADIUM is an element used to refine the grain and improve the mechanical-property balance in steels. It is also used to develop the general properties in many alloy grades.

Our metallurgists can be of considerable help to you in selecting the most economical grades of alloy steel for any application. These men will gladly give unbiased advice concerning alloy-steel composition, heat-treatment and machinability.

We manufacture the full range of AISI grades and special analysis steels as well as carbon steels.

BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation—Export Distributor: Bethlehem Steel Export Corporation

BETHLEHEM ALLOY STEELS

BETHLEHEM STEEL

Designed for Durability!

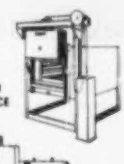
Hoskins Chromel*-equipped Electric Heat Treating Furnaces

Take a good look inside any Hoskins Electric Furnace and you'll quickly understand why they're known for dependability. For beneath their sturdy rugged external construction . . . inside their heavy heat-containing insulation . . . you'll find that every one is equipped with long-lasting heating elements made of CHROMEL resistance alloy.

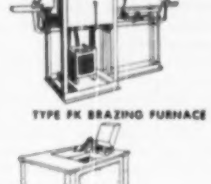
CHROMEL, you know, is the original nickel-chromium alloy that first made electrical heating practical. It's highly resistant to oxidation . . . possesses close-to-constant "hot" resistance between 700° and 2000° F., delivers full rated power throughout its long and useful life. And, as the most vital part of every Hoskins Furnace, it represents your best assurance of long-life satisfactory service.

So next time you're in the market for good, dependable heat treating equipment . . . equipment designed for durability, efficient low-cost operation, and the production of uniformly high quality work . . . you'll do well to get the facts on the Hoskins line of CHROMEL-equipped Electric Furnaces.

Our Catalog 59-R contains complete information . . . want a copy?

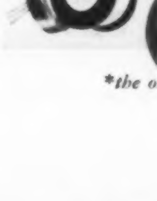


TYPE FR-251 BOX FURNACE



TYPE FK BRAZING FURNACE

TYPE OR-104 POT FURNACE



HOSKINS MANUFACTURING COMPANY

4445 LAWTON AVE. • DETROIT 8, MICHIGAN

NEW YORK • CLEVELAND • CHICAGO

West Coast Representatives in Seattle, San Francisco, Los Angeles
In Canada: Walker Metal Products, Ltd., Walkerville, Ontario

**the original nickel-chromium resistance alloy that first made electrical heating practical*

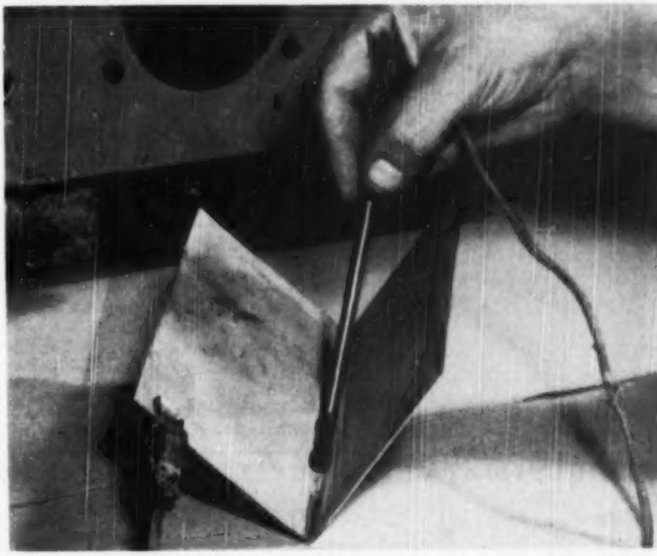
Engineering Digest of New Products

CLEANING METHOD: A simple and economical method for removing weld discoloration from stainless steel has been developed by Armco Steel Corp. It is especially useful in removing discoloration from interior corners. The new method is easy to use. A small amount of acid solution to cover the discolored area, a copper rod, a d-c. power source, and electrical connections are its only parts. The cleaning not only removes weld discoloration but passivates the cleaned area.

The essential parts and assembly of the equipment are shown in the photograph. A copper rod about ¼ in. diameter is bent to a convenient shape. Short pieces of rubber tubing are placed on the rod to keep it from touching the stainless steel and shorting the electrical circuit. Only enough 50% phosphoric acid is poured into the welded corner to contact the copper rod and wet the discolored weld area. The copper rod is connected to the negative terminal of the d-c. power source and the stainless part to the positive terminal. Then the copper rod is passed along the joint to be cleaned. Since the cleaning action depends on the electrical current passing through the solution, the copper rod must not touch the stainless. Weld discoloration is removed quickly; the rod can be moved at a rate of about 2 ft. per min.

This cleaning method will remove light scale and discoloration but will not remove heavy scale or weld slag. Heavy deposits should be removed by chipping or brushing before the cleaning tool is used.

For further information circle No. 1111 on literature request card on p. 820B



PRE-SHAPED STEELS: Steel bar stock cold drawn in special sections to fit specific uses is now available from A. Milne & Co. This new development can minimize or virtually eliminate machining operations in the quantity production of steel component parts. For some parts, machining can be reduced to a simple cut-off operation. The pre-shaped steels are available in a wide variety of sections and in various standard SAE and AISI carbon grades, case hardening, mild and free-cutting steels.

For further information circle No. 1112 on literature request card on p. 820B

TUBE BENDING PRESS: A new hydraulic press, especially designed and tooled for tube bending operations, has been announced by The Gibbons Machine Co. The problem of varying degrees of bend at a particular station of a multiple-index stop has been eliminated in this new press. A new multiple-positive index stop for various degree bends makes certain the operator will have no unpredictable overrun, such as is usually experienced when a four-way hydraulic valve is relied on to control the depth of stroke. The knee width of this new press is only 11 in., which permits reverse bends 5½ in. apart.

For further information circle No. 1113 on literature request card on p. 820B

GRINDING UNIT: A new unit for grinding automotive or other types of pistons where a taper to the conventional relief form is required has been announced by Norton Co. The desired shape is ground by holding the piston between centers, with the head end of the piston being carried in a dog or holder and centered on the master cam spindle center. The bottom end of the piston is supported on a special footstock center carrying a spherical ball bearing. The footstock in which this center seats does not rock by reason of being mounted on the rocking bar as in normal cam or shape grinding practice. It is mounted on a stationary member.

The motion and corresponding amount of piston relief that is ground at any point between centers are proportional to the distance from the footstock pivot. Thus a greater amount of relief is ground at the head of the piston than at the bottom of its skirt, which is nearer the pivot.

For further information circle No. 1114 on literature request card on p. 820B

Engineering Digest of New Products

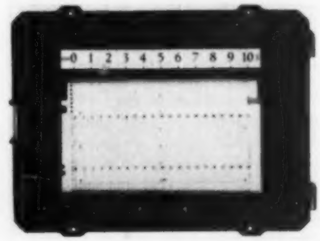
PORTABLE WELDER: A new portable band saw blade welder, now available from Brennen Manufacturing Co., handles 0.050-in. diameter contour-cutting band saw blade, as well as all types of blades up to 1/8 in. flat. The welder is fully automatic; simplified controls assure uniform results at all times. Another feature of the welder is its built-in grinder, designed to remove flash from the weld. It is further equipped with a gage for checking thickness of weld on flat saws. Welding jaws are of solid copper, and the unit is housed in a welded steel case, 7¾ x 12 x 7 in.

For further information circle No. 1115 on literature request card on p. 820B

TUBE BENDING MACHINE: Up to 1000 bends per hour of 1-in. 16-gage steel tubing are now possible on the improved Bend-Ex bender, made by the Paul Machine & Die Works. Operation has been simplified to three quick steps. The machine is adaptable to all bending operations on round, square and rectangular tubing, pipe, light angles, channels and solid bars. Because it is operated with air compression, maintenance is reduced to a minimum.

For further information circle No. 1116 on literature request card on p. 820B

RECORDING STRETCH METER: The percentage stretch or shrinkage of materials being processed through pairs of rolls turning at different speeds is indicated and automatically recorded by the new recording speed-ratio tachometer, offered by the Tagliabue Instruments Div., Weston



Electrical Instrument Corp. The instrument provides a continuous record of roll speed ratio. Operated by two Weston tachometer generators driven by the respective rolls, the new instrument consists essentially of a specially developed Tagliabue Celectray ratio recorder. The ratio meter and recorder can be calibrated in percentage stretch, percentage reduction, or other units which are a function of the speed ratio between two rotating members.

For further information circle No. 1117 on literature request card on p. 820B

TRANSFORMER WELDER: Air Reduction Sales Co. has announced a new transformer welder designed to cover a wide range of applications from light-duty sheet metal jobs to heavy-duty industrial work. Three current ranges selected by insulated tapered plug connectors and infinite hand crank adjustments within each range provide currents from 30 to 250 amp. This permits the use of 1/16 to 3/16-in. diameter electrodes. The Silicone insulation provides a high margin of safety in two ways: It operates safely at high temperatures without breaking down and is water repellent.

This welder employs an automatic hot start control with a hermetically sealed gas-filled time-delay relay magnetic switch that has no open contact. It is of simple construction; there are no delicate relays, rectifiers, fuses or open arcing contacts.

For further information circle No. 1118 on literature request card on p. 820B

Engineering Digest of New Products

LAB FURNACE: New laboratory furnace has been developed by The Despatch Oven Company to fit the expanded needs of testing laboratories in industry. Size and shape of

the new CF line fits better into the space facilities of the average laboratory. Application of cross flow convection heat with extra air volume speeds up preheat time, provides for better penetration of products in the work chamber and reduces time for heat recovery after new loads.

CF line has a temperature range up to 850° F. Provides for maximum heat control accuracy and work chamber uniformity. Swinging doors permit location of the furnace where less headroom is available. Rounded corners and a wrinkle gray finish improve the appearance of the new Despatch oven. Sizes range from 13 x 13 x 13 ft. to 37 x 25 x 37 ft. in the work chamber.

For further information circle No. 1119 on literature request card on p. 820B

PENETROMETER: General Electric X-Ray Corp. has announced a penetrometer of improved accuracy and simplified manufacture. Milled from a single block of aluminum, the new product is used to check the radiographic calibration of X-ray machines, to insure that they are operating properly, and also to test the performance of the machine under varying techniques.

For further information circle No. 1120 on literature request card on p. 820B

SMALL PRONG DIES: A new line of small prong dies, recently introduced by Woodruff & Stokes Co., produces uniform, smooth precision threads. These dies are made with

36 to 360 threads per inch in diameters from 0.250 to 0.016 in. Tolerances can be held to ±0.0002 in. on the pitch diameter. All threads are accurately hobbed and lapped to produce sharp cutting edges and extremely smooth threads.

For further information circle No. 1121 on literature request card on p. 820B

CARBON CONTROL: A new development by Leeds & Northrup Co. makes it possible to measure and control the carbon potential of a furnace atmosphere directly in terms of percentage carbon. By means of this Microcarb control, the surface carbon content of steel can be regulated during heat treating. Atmosphere can be adjusted to increase or decrease carbon potential automatically, as required for the work in the furnace, for surface carburizing, homogeneous carburizing, carbon restoration hardening and annealing.

Principal feature of the carbon control system is a Carbohm detecting element, which projects into the furnace work chamber like a thermocouple and electrically "senses" the carburizing potential of the furnace atmosphere. Connected to this element is a Microcarb controller, which automatically adjusts the flow of carburizing fluid to hold the carbon potential of the furnace gas at any selected value between 0.15 and 1.15% carbon. A Micromax recorder draws a continuous record of percentage carbon as detected by the Carbohm element.

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For further information circle No. 1122 on literature request card on p. 820B

1123. Alloy Annealing Slide Chart

Annealing data for the principal analyses of alloy steels is contained in a convenient slide chart. On one side is listed data for producing spheroidal structures in 40 alloy types by both conventional and isothermal annealing processes. The reverse side carries data for producing lamellar structures, also broken down by conventional and isothermal processes. *Republic Steel Corp.*

1124. Alloy Tubing

New catalog contains complete list of products and prices in warehouse stock of alloy steel tubing. *Timken Roller Bearing Co.*

1125. Alloys

New catalog, "Electromet Ferro-Alloys and Metals", lists over 50 metals and alloys and describes unique technical service offered to the metal industries. *Electro Metallurgical Div.*

1126. Alloys, Brazing

Standard pricing schedule and torch brazing instructions for Silvaloy silver brazing alloys listed in 4-page leaflet. *American Platinum Works.*

1127. Alloys, Fabricated

Catalog available showing cost-cutting fabricated heat treating equipment for higher pay loads and better quality. *Rolock, Inc.*

1128. Alloys, Nickel

New technical bulletin T-6 discusses resistance of nickel and its alloys to corrosion by caustic alkalies. *International Nickel Co.*

1129. Alloys, Nickel

Hastelloy nickel-base alloys are available for fabricating corrosion-resistant screen, cloth and baskets. Also for metal spraying many types of automatic welding and hard-facing. Booklet, "Hastelloy Nickel-Base Alloys", gives full details. *Haynes Stellite Co.*

1130. Beryllium Copper

Helpful engineering information contained in new series of Beryllium copper technical bulletins. *Beryllium Corp.*

1131. Bimetal Elements

64-page catalog written especially to help the design and product engineer select the type and size of thermostatic bimetal element best suited to his temperature-responsive device. *W. M. Chace Co.*

1132. Brake Die Steel

For full information on top quality brake die steel, engineered to machine easily and give long service, write for folder 560. *Bethlehem Steel Co.*

1133. Calcium Cyanide

Technical data on calcium cyanide as a source of nitrogen in steel. Applications of nitrogen-bearing steels. Effects of nitrogen content. Bibliography. *American Cyanamid Co.*

1134. Camera, High Speed

"Magnifying Time", a new folder describing high-speed camera capable of 1000 to 3000 pictures per second. Particularly adaptable for close inspection in machine tool operations and also for measuring flow of liquids as in chemical mixers, coolant flow, etc. *Eastman Kodak Co.*

1135. Castings

Bulletin FC-350 outlines the many advantages of improved Fahrite corrosion-resistant castings. *Ohio Steel Foundry Co.*

1136. Coatings, Metal

Explanations of high-vacuum evaporation of metals and other solids set forth in detail in new 12-page booklet, "Vaporized Metal-Coatings by High Vacuum". *Distillation Products, Inc.*

1137. Control Devices

New 64-page catalog 8303 illustrates over 100 different industrial control devices for temperature, flow, pressure, liquid level, and humidity. *Brown Instrument Div.*

1138. Cryostat

Folder describing the Collins Helium Cryostat which can liquefy helium and maintain any temperature from room temperature down to -454°F. *Arthur D. Little, Inc.*

1139. Dry Cyaniding

Latest developments in the modern dry (gas) cyaniding process, with equipment and its applications, are presented in a new 4-page bulletin. Both liquid quenching and slow cooling and their applications are described. *Surface Combustion Corp.*

1140. Electrodes

New 12-page booklet, "The ABC's of Welding High Tensile Steels", guides buyers and users of low-alloy, low-hydrogen electrodes. It shows the importance and effectiveness of low-hydrogen electrodes in welding low-alloy, high-tensile steels, mild steel under highly restrained conditions and sulphur-bearing free-machining steels. *Arcos Corp.*

1141. Electrodes

Approximate carrying capacity of graphite electrodes is shown in this data sheet, which includes chart comparing carbon and graphite capacity. *International Graphite & Electrode Co.*

WHAT'S NEW

IN MANUFACTURERS' LITERATURE

1142. Electrodes, Welding

New catalog presents complete line of shielded-arc electrodes for welding of mild steels and alloy steels; gives complete specifications, operating characteristics, mechanical properties, and applications. *McKay Co.*

1143. Fasteners

Bulletin announcing a new fastening invention, a pre-assembled nut and lock washer. *Shakeproof, Inc.*

1144. Fatigue Machine

New bulletin describing SF-10-U machine, for vibration testing under conditions of simulated service, with constant-load regulation during test. *Baldwin Locomotive Works.*

1145. Finishing

Alodine coating chemical protects aluminum and its alloys with no plating equipment required. Applied with dip, spray, brush and flow coat, it provides a simple, easy process for lasting, corrosion-resistant finish. *American Chemical Paint Co.*

1146. Forgings

New catalog 51 contains 30 pages covering such topics as type of forgings; where and how to use forgings; turnbuckle dimensions, strengths and related data. Well illustrated with tables and drawings. *Merrill Bros. Co.*

1147. Furnace, Batch Type

New 4-page illustrated folder discusses the completely automatic cycle of the batch-type furnace. Drawings covering the cycle, and suggestions on how to fit it into production lines, are included. New features also described; radiant heating with temperature build-up; vestibule flushing for clean, scale-free parts; compact size — no pit needed; long tray life; controlled quench temperature and agitation. *Holcroft & Co.*

1148. Furnace Controls

Information available on the Speedomax recorder that automatically plots the relationship between two variables, showing one as a function of the other. Tedious compilation and manual plotting by experienced personnel are eliminated. *Leeds & Northrup Co.*

1149. Furnaces

Bulletin T-1420 illustrates and describes Lindberg LI-25 induction heating unit. A ruggedly constructed vacuum-tube type of unit for hard working production-line jobs. Ideal for hardening, brazing and soldering, annealing and stress relieving, hot forming and light forging, shrink fitting and other induction heating applications. *Lindberg Engineering Co.*

1150. Furnaces, Gas Fired

Blueprints available for layouts of 20 mm. — 37 mm. — 40 mm. and larger shell cases, providing compact and efficient heat treating facilities with most economical investment. *Despatch Oven Co.*

1151. Furnaces, Lab

Bulletins 315 and 515 describe furnaces for low and high-temperature operation. Five different models for analysis, control and production in chemistry, metallurgy and manufacturing. Also bulletin 310 on "Unit-Package" electric tube furnace for determination of carbon or sulfur. *Burrell Corp.*

1152. Furnaces, Rotary

Bulletins 801-804 and 1210-1212 illustrate and describe various continuous and batch rotary furnaces suitable for carburizing and other general and atmosphere heat treatment. *American Gas Furnace Co.*

1153. Furnaces, Salt Bath

4-page bulletin describes construction and operating characteristics of new salt bath furnace employing totally submerged electrodes. Well suited for heat treating in temperature range 1700 to 2400°F. *Ajax Electric Co.*

1154. Gas Generator

Bulletin 1-11 describes how new inert gas generator Model 1 MIHE, rated at 1000 c.f.h., obtains the same analysis of inert gas, regardless of demand. Fully automatic, it gives accurate proportioning and assures precise analysis over full operating range. Ratio control adjusts for manufactured, natural, propane, butane or refinery gases. *C. M. Kemp Mfg. Co.*

1155. Gray Iron

Revised summary of Gray Iron specifications available in 4-page bulletin containing a resume of fourteen separate sets of gray iron specifications including a change in ASTM A-159-47 to ASTM A-159-49T and the addition of two new specifications covering automotive irons 113 and 114. *Gray Iron Founders' Society.*

1156. Hardness Testers

Bulletin DH-114 contains full information on Tukon hardness testers for use in research and industrial testing of metallic and nonmetallic materials. Also included is bulletin DH-7, giving experiences in various fields. *Wilson Mechanical Instrument Co.*

1157. Heat Treating

Folder describes new improved Pentrate process for rapid, durable, economical black finishing for steel. *Heatbath Corp.*

1158. Heat Treating

Pressed steel lightweight sheet alloy heat treating units furnished in any size, design or specification. Write for full information on this. *The Pressed Steel Co.*

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

1159. Heavy-Duty Forgings
16-page booklet on "Heavy-Duty Forgings", profusely illustrated, shows forgings of all sizes in every phase of development from ingot to finished product. *A. Finkl & Sons Co.*

1160. High-Temperature Testing
For precise hi-temperature testing, send for illustrated technical folder on Marshall equipment. *L. H. Marshall Co.*

1161. Induction Heating
For more economical manufacture in designing and redesigning present products, send for copy of "Design and Manufacture for Profit" with full details on Tocco Induction Heating for brazing, hardening, soldering, forging or shrink-fitting. *Ohio Crankshaft Co.*

1162. Laboratory Apparatus
Leaflet describes testing and scientific equipment available for metallurgical laboratory. *Harshaw Chemical Co.*

1163. Lubrication of Hot Metals
New bulletin 426 describes how (DAG) colloidal graphite can solve your lubrication problems in hot metal-forming operations. *Acheson Colloids Corp.*

1164. Metallograph
12-page catalog describes this completely new all-in-one desk-type unit for metallographic work. *American Optical Co.*

1165. Metal Plates
For full information on solid or clad plates in the exact grade you need to combat corrosion, oxidation and contamination, write for new A-L Plate Book. *Allegheny Ludlum Steel Corp.*

1166. Metal Spinning
New Spincraft data book — a valuable reference bulletin that illustrates lower costs made possible through pioneering developments in working of metals. *Spincraft, Inc.*

1167. Microscopes
Catalog D-1010 illustrates and describes new E series of microscopes for the most exacting research work. *Bausch & Lomb Optical Co.*

1168. Motor-Generators
New 8-page, two-color booklet, GEA-5506, covers synchronous motor-generator sets from 30 to 8000 kw for such industrial applications as rolling-mill motors, electrolytic refining of ores, etc. Illustrates four typical installations and describes the construction features. *General Electric Co.*

1169. Oils, Cutting
For the right combination to suit your specific requirements, send for your copy of "Cutting Fluid Facts". *D. A. Stuart Oil Co.*

1170. Oils, Cutting
Interesting facts on more efficient and economical plant operation through use of right lubricants described in "Metal Cutting Fluids". *Cities Service Oil Co.*

1171. Organic Solvents
New 64-page booklet, "Organic Solvents", gives definitions and explanations of terms used in the trade; also extensive tables of significant properties of the various commercial organic solvents. *Central Solvents & Chemicals Co.*

1172. Polishing and Buffing
Bulletin entitled "Acme Straightline Automatic Polishing and Buffing Machines" illustrates and describes a machine for every type of production polishing and buffing job. *Acme Mfg. Co.*

1173. Potentiometer, Portable
Bulletins 270 and 270-A describe portable potentiometers in a selection of ranges up to 1.6 volts. *Rubicon Co.*

1174. Precision Castings
8-page, profusely-illustrated brochure describes Mircastings, with many application pictures and details. *Alloy Precision Castings Co.*

1175. Presses, Powder
Powder metallurgy is being chosen for the manufacture of many products because of the economical high-speed production possible. Send for illustrated catalog showing the complete line of Kux presses available for every phase of this important industry. *Kux Machine Co.*

1176. Pyrometer
Catalog 100 describes the new Pyro radiation pyrometer for reading spot temperatures instantly in heat-treating furnaces, kilns, forgings and fire boxes. In two double-ranges for all plant and laboratory needs. *Pyrometer Instrument Co.*

1177. Quenching Oil
New technical bulletin F8 describes triple-action quenching oil. Accelerators provide deeper hardening and reduced distortion. *Park Chemical Co.*

1178. Refractories
Revised bulletin entitled "Lumnite Refractory Concrete" discusses latest available information on refractories and heat-resistant concrete. *Lumnite Div., Universal Atlas Cement Co.*

1179. Refractories
Complete details on refractory cements for every nonferrous melting operation are available in catalog 863. *Norton Co.*

1180. Refractories
New Insulation Chart IN-6D gives recommended insulation for every temperature range from minus 400°F to plus 3000°F. *Johns-Manville Corp.*

1181. Sawing
Bulletin 2-MP illustrates the circular sawing of metals, and new automatic triple-chip method for sawing stock up to 6 inches accurately without burrs. *Motch & Merryweather Co.*

1182. Saws
Catalog 49 describes complete line of metal-cutting saws, covering 35 models in 10 basic types, and including the world's fastest automatic production saw, the largest hydraulic hack saws, and some of the most widely used small shop saws. *Armstrong-Blum Mfg. Co.*

1183. Specimen Mount Press
New bulletin describing AB Speed Press. Features include use of preheated premolds, rapid closing and universal application for thermo-setting or thermoplastic materials in 3 sizes. *Buehler Ltd.*

1184. Steel, Alloy
New 24-page booklet, "How to Specify and Buy Alloy Steel with Confidence", emphasizes the importance of careful selection, positive knowledge of properties and accurate heat treatment in purchasing alloy steels. *Jos. T. Ryerson & Son, Inc.*

1185. Steel, Nitrogen-Bearing
Technical data on effects of nitrogen. Applications of nitrogen steels. Calcium cyanide as a source of nitrogen. Bibliography. *American Cyanamid Co.*

1186. Steels, Stainless
Weekly lists with analyses of all plates in stock will keep you regularly informed on latest data. *G. O. Carlson, Inc.*

1187. Testing
New precision-built, self-contained, portable Velometer gives instant, accurate reading of air velocities — anywhere. Full details available in bulletin 2448-G. *Illinois Testing Labs.*

1188. Thermocouples
Catalog 59-R tells complete story about use of Chromel-Alumel couples and extension leads. *Hoskins Mfg. Co.*

1189. Thermocouples
Two new sections are now included in the thermocouple catalog, listed as Sections 12 and 23, covering aircraft thermocouples and quick coupling connectors. *Thermo Electric Co.*

1190. Tool Steel Selector
Selector is handy chart featuring general data and heat treating data on non-deforming, water hardening, shock-resistant, hot work, and high speed tool steels and hollow die steels. *A. Milne & Co.*

1191. Tool Steels
"A Progress Report on 'E' Steel" outlines the many advantages of these faster, smoother J & L tool steels for increased production on difficult jobs as illustrated in 11 case histories of actual shop tests. *Jones & Laughlin Steel Corp.*

1192. Turbo-Compressors
Bulletins available as follows: Data book 107, Gas Boosters 109, Four-Bearing 110, Blast Gates 122, Foundry 112. Descriptive bulletin 127 and Technical bulletin 126. Send for each by number for particular application. *Spencer Turbine Co.*

1193. Vacuum Metallurgy
Bulletin entitled "National Research Corp. and Vacuum Metallurgy" gives brief resume of the vacuum metallurgical operations and background of this company and of the research and development facilities and services available to the metallurgist. *National Research Corp.*

1194. Vacuum Pumps
Bulletin V-45 describes complete range of high-vacuum pumps for insuring positive lubrication and long equipment life. *Kinney Mfg. Co.*

1195. Valves, Fittings
48-page catalog details stainless steel valve, fitting and accessory line, with engineering drawings, weights, dimensions, size ranges, materials, corrosion data, nomenclature and design information. *Cooper Alloy Foundry Co.*

1196. Welding
For complete information on fast and economical welding of aluminum, aluminum or silicon bronze, stainless and nickel clad steels, send for your copy of the Aircomatic welding bulletin ADC-661 A. *Air Reduction Sales Co.*

1197. Welding
Information available on Oxweld W-17 blowpipe with right welding head or cutting attachment for high efficiency and economy in all types of welding processes. *Linde Air Products Co.*

1198. Welding Rods
24-page illustrated booklet describes welding rods and procedures, including tobin bronze, prosphor bronze, everdur, manganese bronze, copper, super-nickel and other alloys. *American Brass Co.*

[• If mailed from countries outside the United States, proper amount of postage stamps must be affixed for returning card]

METAL PROGRESS
7301 Euclid Avenue, Cleveland 3, Ohio

December, 1950

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WE INCREASED PRODUCTION 71% WITH J&L "E" STEEL

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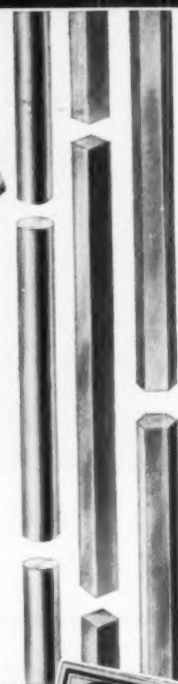

(a story* about how to win customers and influence prospects)

"Got a minute? Well, let me tell you about what happened at our machine shop a couple of months ago when we first tried that new J&L "E" Steel. You wouldn't believe it was possible! (Confidentially, neither did we until we proved it to ourselves.) Here's what happened.

"We got an order to produce a big lot of plunger stops for solenoid starter switches. They're tricky to run, and you've got to be pretty careful every second. We'd read about "E" Steel in some of J&L's ads, and decided we might try some on this job.

"So we ordered some 17/32" E-33 "E" Steel stock, set up our B&S #2 and B&S #0 Automatics and began to turn out parts. We had used B-1113 for this job before and had been getting 350 pieces per hour. But we soon realized we could machine much faster with "E" Steel, and **we kept increasing speed until we were getting an average of 600 parts per hour. That's a 71% production increase!**

"Next thing we discovered was that our tools were lasting twice as long and the chips were coming off better with "E" Steel than they did with B-1113. We also found that the finish on the parts had improved from 20% to 25%.

"That's why we've been using "E" Steel. We turn out work much faster and can take on more jobs. Our men like the way "E" Steel machines and our customers get better parts and better service. Everybody benefits!"

Get your copy of the booklet titled "A Progress Report on 'E' Steel." It outlines a series of 11 case histories from machine shops that have used "E" Steel with excellent results. Write for your copy.

**Based on an actual case history.*

"E" Steel (U.S. Pat. No. 2,484,231) is easily identified by the distinctive blue color on the end of every bar.

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Please send me a free copy of "A Progress Report on 'E' Steel."

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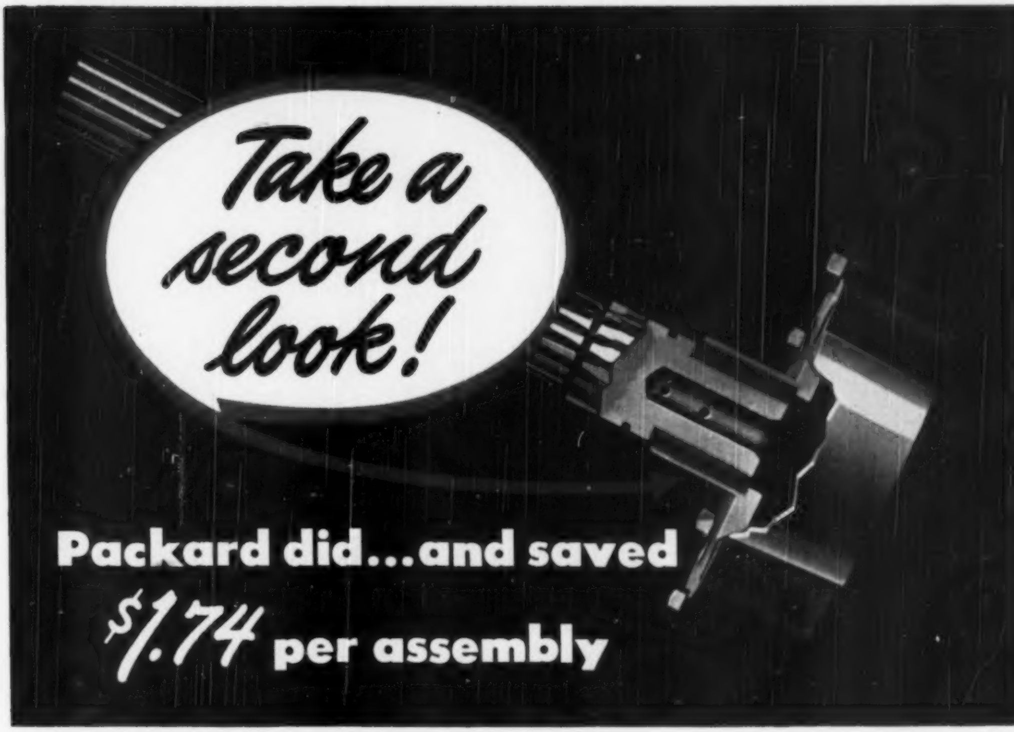
JONES & LAUGHLIN STEEL CORPORATION

From its own raw materials, J&L manufactures a full line of carbon steel products, as well as certain products in OTISCOLOY *and* JALLOY *(hi-tensile steels).*

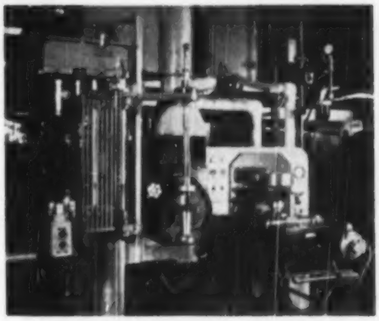
PRINCIPAL PRODUCTS: HOT ROLLED AND COLD FINISHED BARS AND SHAPES • STRUCTURAL SHAPES • HOT AND COLD ROLLED STRIP AND SHEETS • TUBULAR, WIRE AND TIN MILL PRODUCTS • "PRECISIONBILT" WIRE ROPE • COAL CHEMICALS



with TOCCO* Induction Brazing

THIS is the "planetary output shaft" for the Packard Ultramatic Transmission. It was originally designed to be made from a forging, but Packard engineers "took a second look" and determined that a slight design change, using a casting and a steel shaft, permitted taking advantage of Induction Brazing. This resulted in a savings of $74,325 in the equipment and tooling for production, in addition to the actual labor and materials savings of $1.74 per assembly.

When designing *your* new product, or redesigning present products for more economical manufacture, you will profit by considering TOCCO Induction Heating for brazing, hardening, soldering, forging or shrink-fitting. Designing for Induction Heating pays off!



A 30 KW, 10,000 Cycle TOCCO Unit Brazes 45 Assemblies per hr.

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. . . Sucker Rods for Heavy-Duty Deep Well pumping now GUARANTEED to 90,000 p.s.i.—whereas the previous high has been 70,000 p.s.i.—another triumph for *"the right steel in the right place"*

With many wells ranging from 6,000 to 12,000 feet in depth, pumping places a tremendous strain on the sucker rod string entrusted with bringing the oil to the surface. Each slender sucker rod unit—only 25 or 30 feet long and ⅝" to 1" in diameter—must be capable of supporting the multi-ton weight of the entire string . . . must carry the weight of the oil rising to the surface . . . must stand up under the constant whipping and reversing action of pumping.

For more than five years, Republic's field-mill-laboratory metallurgical team has worked with this manufacturer's own metallurgists—to produce a stronger, longer-lasting sucker rod for deep well pumping.

The result? The "right steel in the right place" not only increased yield strength by a phenomenal 30%, but it did more. Coupled with this added strength are great endurance and high fatigue resistance. And because the steel is used in its normalized and tempered condition, there is no sacrifice in needed corrosion-resistance.

This is but one of many important oil field applications in which Republic Alloy Steels and 3-Dimension Metallurgical Service have resulted in improved performance . . . lower production costs . . . higher productivity. What has been accomplished here can reasonably be done in *other* applications, in *other* industries.

Are you using "the right steel"? Why not call on Republic's 3-Dimension Metallurgical Service to work with your own metallurgists toward finding it—and with it, new economies and new profits. Call your nearest Republic representative today.

REPUBLIC STEEL CORPORATION
Alloy Steel Division • Massillon, Ohio
GENERAL OFFICES • CLEVELAND 1, OHIO
Export Department: Chrysler Building, New York 17, N.Y.

Republic REPUBLIC STEEL
ALLOY STEELS

Pig Iron, Bolts and Nuts, Tubing

Do all this with *One* OXWELD Blowpipe

Trade-Mark

- Cut steel up to 12 in. thick
- Bevel parts for fabrication or repair
- Gouge grooves of many sizes and contours
- Deseam semi-finished steel forms
- Cut risers and "wash" pads
- Prepare plate edges for welding
- Remove rivets and pierce holes
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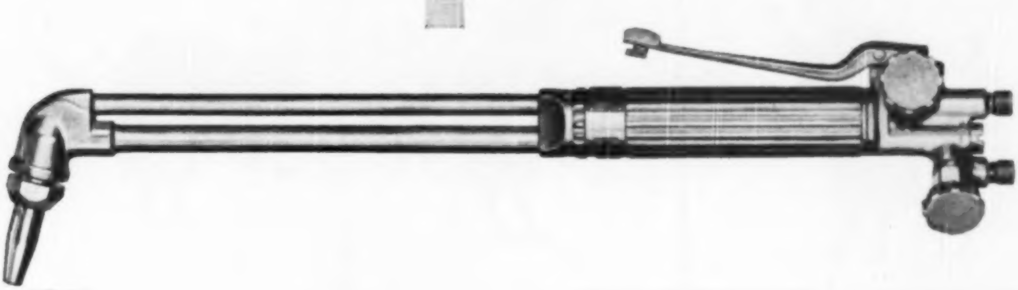
- Cut guided circles and straight lines
- Scrap obsolete equipment for profit



Whether your work includes one or more than one of these jobs, the Oxweld C-32 Blowpipe will save you time and money. This all-purpose cutting blowpipe, with its wide variety of inexpensive nozzles and attachments, easily handles these jobs—and many others—with outstanding efficiency, speed, and convenience.

Like all Oxweld products, the C-32 is built to give you many extra years of economical and **trouble-free service** under every condition of use. Available in your choice of 3 lengths (20-, 26-, and 32-in.) and 3 head angles (75-, 90-, and 180-deg.) to suit your exact needs. Write or phone today for full information about this cutting blowpipe — or regarding welding blowpipes, regulators, cutting machines, or acetylene generators.

The terms "Linde" and "Oxweld" are registered trade-marks of Union Carbide and Carbon Corporation or its Units.

Linde
Trade-Mark

THE LINDE AIR PRODUCTS COMPANY
Unit of Union Carbide and Carbon Corporation
30 East 42nd Street UCC New York 17, N. Y.
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SELF-SERVICE
MEATS
FRUIT
BREAD
CAKE

You can make important savings in fuel by taking advantage of the quick heating characteristics of J-M Insulating Fire Brick. These light-weight brick permit a quicker rise to proper operating temperature in the furnace because of their low heat storage capacity, and low thermal conductivity. Where furnaces are being intermittently operated these are two especially important characteristics.

These same insulating materials can also be obtained in large size units called Johns-Manville Insulating *Fireblok*. This product has many advantages over the smaller size fire brick for certain types of jobs . . . from both a construction and stability standpoint. The Fireblok units can be quickly applied because they are easy to cut and fit. Fireblok insulations provide additional heat savings because they reduce the number of joints, and require less mortar for bonding.

It will pay you to let a Johns-Manville insulation engineer explain the many ways in which you can save by using these insulations in your furnaces. Just write for further information to Johns-Manville, Box 290, New York 16, N. Y.

	JM-1620	JM-20	JM-23	JM-26	JM-28	JM-3000
Densities, lb per cu ft	29	35	42	48	58	63-67
Transverse Strengths, psi	60	80	120	125	120	200
Cold Crushing Strengths, psi	70	115	170	190	150	400
Linear Shrinkage†, percent	0.0 at 2000 F	0.0 at 2000 F	0.3 at 2300 F	1.0 at 2600 F	4.0 at 2800 F	0.8 at 3000 F
Reversible Thermal Expansion, percent	0.5—0.6 at 2000 F	0.5—0.6 at 2000 F	0.5—0.6 at 2,000 F	0.5—0.6 at 2000 F	0.5—0.6 at 2000 F	0.5—0.6 at 2000 F
Conductivity* at Mean Temperatures						
500 F	0.77	0.97	1.51	1.92	2.00	3.10
1000 F	1.02	1.22	1.91	2.22	2.50	3.20
1500 F	1.27	1.47	2.31	2.52	3.00	3.35
2000 F	—	1.72	2.70	2.82	3.50	3.60
Recommended Service						
Back up	2000 F	2000 F	2300 F	2600 F	2800 F	3000 F
Exposed	1600 F	2000 F	2300 F	2600 F	2800 F	3000 F

†24-hr. simulative service panel test for JM-3000; 24-hr. soaking period for other brick.

*Conductivity is expressed in Btu in. per sq ft per F per hour of the designated mean temperatures.

Note: Above tests are in accordance with A.S.T.M. tentative standards.

Johns-Manville *first in* **INSULATIONS**

Refractory Cement Selection Made Easy

for ferrous melting furnaces

Type of furnace	metals melted	use of cement	Norton number	cement recommended description	maturing temp.	max. temp.	how applied
indirect arc	alloy iron and malleable iron	lining	RA1144	coarse grain Alundum* cement	2100°F	2950°F	rammed
		patching	RA1160		1850°F		rammed
		troweling around electrodes	RA162	fine grain Alundum cement	1850°F	2950°F	troweled
direct arc	alloy steel and malleable iron	lining roof and around electrodes	RA1144	coarse grain Alundum cement	2100°F	2950°F	rammed
		lining roof and around electrodes	RA1195	very coarse grain Alundum cement	2000°F	3100°F	rammed
		patching	RA1160		1850°F		rammed
high frequency induction	stainless steel and refractory alloys	lining	RM1169	very coarse grain Magnorite* cement	2100°F	3250°F	rammed (dry)
		patching large furnaces	RM868	medium grain Magnorite cement	2200F°	2750°F	rammed
		patching small furnaces	RM1171	medium grain Magnorite cement	2000°F	2900°F	troweled or rammed

for non-ferrous metal-melting furnaces

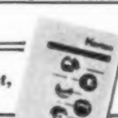
Type of furnace	metals melted	use of cement	Norton number	cement recommended description	maturing temp.	max. temp.	how applied
low frequency induction	refractory alloys, cupronickel, nickel silver, high copper alloys Al, Te, Si bronzes	lining	RM1140	coarse grain Magnorite cement	2300°F	3250°F	rammed
	nickel silver	lining	RA1195	very coarse grain Alundum cement	2000°F.	3100°F	rammed
	brasses not more than 90% copper or less than 10% zinc	lining	RA1144	coarse grain Alundum cement	2100°F	2950°F	rammed
indirect arc	nickel and high nickel alloys	lining	RA1144	coarse grain Alundum cement	2100°F	2950°F	rammed
		patching	RA1160		1850°F		
crucible melting furnaces■	brasses and bronzes	lining and patching	RC1188	coarse grain Crystolon* cement	2000°F	3050°F	rammed
		lining and patching	RC1133	coarse grain Crystolon cement	2100°F	2950°F	rammed
		lining and patching	RC1204	coarse grain Crystolon cement	2000°F	2900°F	rammed
reverberatory furnaces ▼	brasses and bronzes	lining and patching	RC1188	coarse grain Crystolon cement	2000°F	3050°F	rammed
		lining and patching	RC1133	coarse grain Crystolon cement	2100°F	2950°F	rammed
		lining and patching	RC1204	coarse grain Crystolon cement	2000°F	2900°F	rammed

■ Cement not in contact with metal, used in combustion chamber.
▼ Cement in contact with metal. * Trade-marks Reg. U. S. Pat. Off. and Foreign Countries.

This Chart is a synthesis of several charts from a new 16-page bulletin just prepared by Norton refractory engineers, after exhaustive laboratory and field tests.

Titled "Norton Longer Lasting Refractory Cements," this fact-packed bulletin covers the properties, selection and application of the correct cement for your refractory requirements.

Write for Bulletin 863. Norton Company, 320 New Bond Street, Worcester 6, Mass.



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Making better products to make other products better

Special REFRACTORIES

METAL PROGRESS

Ernest E. Thum, Editor

Vol. 58 ***December, 1950*** ***No. 6***

Table of Contents

Now, a high strength ALLOY that *Machines Easily*

Never before an alloy steel that offered you these combined advantages! With Ryerson Rycut you can speed up production—reduce downtime—get a better surface on your machined product! This remarkable medium carbon alloy machines 25% to 50% faster and at much higher tensiles than other alloys of the same type! It actually doubles—may even quadruple your tool life! And grinding is often unnecessary because many parts may be finish machined.

Though offering you all these time and money saving advantages, the initial cost of Rycut is practically the same as that of standard medium carbon alloys!

Rycut responds uniformly to the conventional oil-quench method of heat treatment. It may also be flame or induction hardened. And when heat treating Rycut, your Ryerson alloy certificate guides you to the required results.

Rycut is available for immediate delivery—annealed or heat treated—in rounds, flats or squares, in a wide range of sizes. For test samples or a large shipment, contact your nearby Ryerson Plant.

PRINCIPAL PRODUCTS

CARBON STEEL BARS—Hot rolled & cold finished
STRUCTURALS—Channels, angles, beams, etc.
PLATES—Many types including Inland 4-Way Safety Plate
SHEETS—Hot & cold rolled, many types & coatings
TUBING—Seamless & welded, mechanical & boiler tubes
ALLOYS—Hot rolled, cold finished, heat treated
STAINLESS—Allegheny bars, plates, sheets, tubes, etc.
TOOL STEEL—Oil and water hardening
REINFORCING—Bars & Accessories, spirals, wire mesh
MACHINERY & TOOLS—For metal fabrication

JOSEPH T. RYERSON & SON, INC. PLANTS AT: NEW YORK • BOSTON • PHILADELPHIA • CINCINNATI • CLEVELAND DETROIT • PITTSBURGH • BUFFALO • CHICAGO • MILWAUKEE • ST. LOUIS • LOS ANGELES • SAN FRANCISCO

RYERSON CERTIFIED STEELS

RYERSON STEEL

The Chairman of one of the principal copper and brass fabricating companies believes that our current resources in copper, zinc, aluminum and lead are sufficient for foreseeable rearmament and stockpiling programs with enough left over for almost all normal civilian demands.

The Supply of Nonferrous Metals*

IT IS CLEAR that the nonferrous metals are among the most important keys to the national economy in the period immediately ahead. Probably no other products or services, with the possible exception of electric power, will do as much to determine the extent to which we can meet the needs of the armament program without cutbacks in the production of civilian goods.

The assumption here is that there will be no shooting war after the clean-up in Korea, but that stockpiling and the arming of the country and of the Atlantic nations will be accelerated.

Fabricating Capacity — Our nonferrous fabricating industries have the plant capacity to turn out enough products both for the expanded military program and for a high rate of civilian consumption. There are also unused facilities left over from the last war, Government plants maintained in "mothballs". Most companies meanwhile have expanded their capacity for peacetime production and have improved their plants and equipment. Technical research has added to the quality and diversity of products.

As an example of productive capacity, we might cite figures for the copper industry. Fabricators in August of 1950 consumed 137,000 tons of copper, or at the rate of 1,644,000 tons a year. This rate was approximately that of 1943 and 1944, our biggest war years. Considering that wartime production is in the heavier gages, it is clear that our capacity to fabricate under emergency circumstances is far above that of the last war, perhaps as much as 25% higher, or at the rate of 2,000,000 tons a year without use of idle Government plants.

In fact, wherever we look among the industries of this nonferrous group, we find that the limiting factor in the period ahead will not be capacity to fabricate metals or manufacture finished products, but the availability of ingot.

Ore Supply — It is often said that higher prices for copper will encourage more mining. Such statements are misleading and contrary to the facts. These are:

First, that the production of marginal, high-cost copper mines adds only very slightly to the available metal. Furthermore, most of the high-cost mines have been in production through the war and postwar period. The greatest domestic mine production of copper so far recorded was in 1943, when the total was 1,114,149 tons. The seven largest producers accounted for over 1,000,000 tons of this whereas 210 small mines, many of them aided by direct Government subsidies, produced only 83,000 tons! There is no hope that even present high prices, which have stimulated over-all production somewhat, will provide any important contribution to the supply of available metal.

Second, it takes as much as five years to bring a new copper mine into production, and surely not less than three years, even under emergency condi-

*Paper read before the ⊕ Business Forum, 32nd National Metal Congress and Exposition, Chicago, Oct. 26, 1950.

By C. Donald Dallas
Chairman of the Board
Revere Copper & Brass, Inc., New York City

tions when ordinary economies are ignored. As a matter of fact, there are but few bodies of copper ore awaiting development in the United States. We hear of the San Manuel mine in Arizona. This is usually described as our largest undeveloped copper reserve. It is still many years and $50,000,000 away from becoming a real factor in the U. S. copper production. The same is true of the White Pine area in Michigan.

The only nearby increases to be expected in copper production abroad will be from African sources. These should increase the world's supply of the metal by an additional 6000 tons a month beginning in 1951, and by another 6000 in 1952.

Charles Donald Dallas

One of the many distinguished graduates of Illinois Institute of Technology (then, 1902, Armour Scientific Academy), C. Donald Dallas entered the copper and brass industry naturally, following the footsteps of his Canadian-born father. In 1908 they organized the Dallas Brass and Copper Co., to act as sales representatives of eastern mills, and by 1925 the firm owned two fabricating plants. In 1928 Mr. Dallas took the lead in forming a merger with five other sizable companies into Revere Copper and Brass, Inc., now the second largest in the United States in fabrication capacity.

Enough Copper for Real Needs

However, although we cannot expect increases in copper supply to correct the current shortage of metal, the situation is by no means so serious as it appears.

Let's look at what has happened this year:

Stimulated by the abnormal demand since the Korean episode and the imposition of the copper tariff, prices have risen and deliveries to customers have depleted stocks in the hands of both producers and fabricators. Producers' stocks on Aug. 31 were less than two weeks' supply — an irreducible minimum. Fabricators' holdings meanwhile had declined and are well under the 90-day stock considered normal.

The rise in price was from a low of 16¢ in 1949 to a nominal — or, more accurately, fictitious — figure of 24½¢. How unreal this price is may be judged from the fact that recently over 30¢ a pound has been paid in the gray market.* This is inflation, and the victims are all of us who need copper in our factories, or who buy copper products in the market place.

This decline in available stocks, and the rise in price, was in the face of rising supply and no clearly defined actual increase in needs.

Let us consider, for instance, that actual consumption of copper by American industry in 1949 (which could by almost any standard be considered a good year) amounted to an average of 88,000 tons a month. It is encouraging that supplies available during the first eight months of this year averaged about 87,000 tons a month of domestic copper, and there was another 40,000 tons a month of net imports, thus making available 127,000 tons — 39,000 tons more than the 1949 rate of consumption monthly by industry.

But the increased military needs for copper under the armament program have been unofficially estimated at about 13,000 tons a month. Stockpiling averaged 18,700 tons a month for the first eight months of the year. Assuming a major acceleration of stockpiling to 30,000 tons a month (which it hasn't reached yet) such stockpiling plus consumption for military needs totals 43,000 tons a month. This, subtracted from the current supply level of 127,000 tons a month, leaves 84,000 tons available for industry as against the average of 88,000 tons consumed in 1949.

However, this isn't the whole story. Exports are now being rigidly curtailed, and under the stimulus of high prices we may expect that a little additional metal will be somehow squeezed out. Net imports may well be upped to 50,000 tons a month, and domestic supplies to about 90,000 tons, for a supply total of 140,000 tons a month which, after stockpiling and military needs, will leave something like 97,000 tons a month for civilian industry and peacetime uses which last year needed only 88,000 tons.

This does not presage any great hardship for the American citizen. It seems evident that the wholly abnormal conditions of recent months, plus the clear results stemming from our monetary inflation, have caused the illusion of tremendous shortages of copper which in fact do not exist.

In view of present high prices and abnormal demand for copper, we are led to question seriously

*Editor's Footnotes: On the day Mr. Dallas was speaking the Chicago *Journal of Commerce* quoted electrolytic copper at 24½¢ but copper futures for November in New York at 30¢ per lb.

whether an accelerated rate of stockpiling is justified. Our supplies of copper are principally of Western Hemisphere origin, and the total production of this hemisphere has exceeded 2,000,000 tons in several war years. This was actually 25% more than we used in America in our heaviest war years and was available for shipment to our Allies. In addition, we actually stockpiled 481,000 tons of copper, beyond requirements, during these years. The fact is that in the event of war, all the stocks of copper in the United States, in anybody's hands, become our stockpile for military purposes, and all the production of new metal in the Western Hemisphere is at our disposal.†

Zinc, Aluminum and Lead

Recent shortages of zinc have been even more acute than of copper. Stocks of slab zinc have been reduced this year from 94,000 tons to 10,000 tons at the end of September — less than five days' production. Domestic production has been much below current demand from industry plus stockpiling. But this industrial demand and stockpiling are as much inspired by fear as anything else, and the stockpiling program in zinc has created a similar situation to that in copper.‡

Imports of zinc in 1950 have roughly balanced stockpiling, so the domestic production has been entirely available to industry. This production has been 75,000 tons a month, which compares with consumption by industry in 1949 of 59,000 tons a month. So you see that even with increased stockpiling, and increased military needs, there will still be much zinc left for industry.

Figures on aluminum are not so precisely available as in the case of the other metals. There are excess fabricating facilities available in this industry, but as in the case of the other metals there is insufficient supply of ingot for the present level of demand. The principal bottleneck here appears to be electric power, needed in the reduction process and not subject to ready increase. Wartime plants were built in the areas of high electric power costs, and these have been to some extent dismantled in the intervening years. The military program will take a greater proportion of aluminum production than is true of copper, but nevertheless there appear to be enough supplies of aluminum in sight to maintain an industrial level for civilian goods of substantial height.**

Lead is the least scarce of the important nonferrous metals and does not appear likely to be a problem under any conditions now foreseeable.††

This rapid survey, I think, has made the point that the current shortages of the nonferrous metals which plague industry are the result of excessive demand from industry and government. There has been fear-inspired buying; there has been hoarding; these have caused the shortages. There is actually enough metal to support the 1949 level of civilian output, the present high rate of stockpiling, and military demands as now forecast.

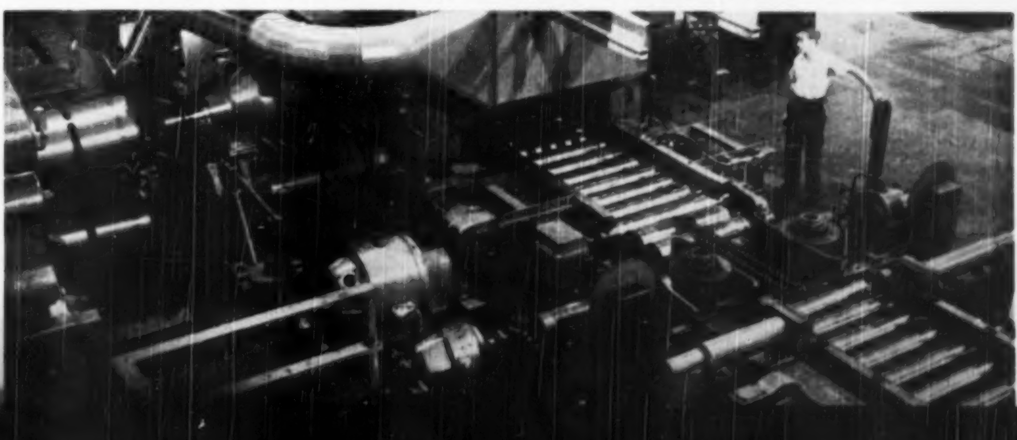
†Mr. Dallas does not mention the enormous actual "stockpile" of pure and alloyed copper existing in the United States. All articles made of these materials are quite permanent, and represent an enormous accumulation. Normal recoveries of copper from demolition scrap and obsolescent articles (junk) amount to about 30% as much as the refinery production from ore and could be greatly expanded by appropriate incentives.

‡Chicago *Journal of Commerce* on Oct. 26, 1950, quotes custom smelters' price of special high grade at 18.75¢ per lb. delivered, whereas "New York Zinc Futures" are quoted at 28.75¢ for November delivery.

**See *Metal Progress* for August 1949 (p. 204) and July 1950 (p. 56). Wartime peak of primary ingot capacity was 1,162,000 tons per year. Total economical capacity in the United States is now about 680,000 net tons per year. American consumption for some months past has been considerably more than at this rate, the difference being largely supplied by the 350,000-ton capacity plant of Aluminum Co. of Canada at Arvida, Quebec. On Oct. 27 the National Production Authority issued Order M-6 instructing the various factors in the fabricating industry to accept "rated orders" (popularly called DO orders — D for defense) up to approximately 25% of their scheduled shipments.

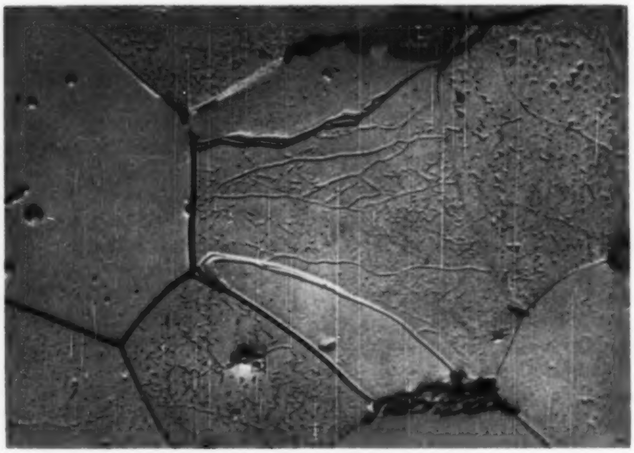
††*Journal of Commerce* quotations: Custom smelters' price for common lead, New York, 16.00¢ per lb.; lead futures, New York, 17.40¢ for December.

Vertical Edgers in Return Table of Reversing Hot Mill at Revere's Baltimore Plant



Grand Prize, 1950 Metallographic Exhibit

Veining in Ferrite



Metallographer: Sten O. Modin, Metallografiska Institutet, Stockholm, Sweden
Class 3: Irons and alloy steels in wrought condition
Material: Rolled bessemer steel bar, 15 mm. square

C	Si	Mn	P	S	N
0.09%	—	0.20	0.028	0.005	0.014

Heat treatment: Normalized at 950° C. (1750° F.)
Etching Reagent: 4% picric acid in alcohol followed by an alkaline solution of sodium picrate
Magnification: 1500 diameters
Structure: Veining in ferrite
Illumination: Oblique

With 355 individual entries submitted by 102 contestants, the Metallographic Exhibit held during the National Metal Exposition in Chicago was the largest in the five-year history of this annual event. A healthy trend is also noted in the increasing foreign representation, about 40% of the contestants — including the grand prize winner — sending samples of their work from Sweden, Finland, Great Britain, Austria, Holland, Spain, Belgium, Australia, and Japan. The judges found several examples of "perfect metallographic technique" — a dilemma resolved by awarding the grand prize on the further criterion of the difficulty of the subject.

Heating of steel in a neutral carrier gas plus methane and ammonia can produce various effects with minimum distortion ranging from carbon restoration or superficial nitriding to fairly deep and complex cases, depending on the gas mixture and heating cycle.

Carbo-Nitriding in Present Practice

A VERY considerable number of articles has appeared in the technical press in the last five years concerning the carbo-nitriding process. The word "carbo-nitriding" is used advisedly, not so much because the present author believes he coined the word, but because it has been included in the list of standard terms relating to heat treatment by the joint committee of the American Society for Metals, the American Foundrymen's Society, the American Society for Testing Materials and the Society of Automotive Engineers. This definition for carbo-nitriding is:

"A process in which a ferrous alloy is case hardened by first being heated in a gaseous atmosphere of such composition that the alloy absorbs carbon and nitrogen simultaneously, and then being cooled at a rate that will produce desired properties."

A student of the literature will appreciate that this term embraces operations variously described as "dry cyaniding", "gas cyaniding", "nitrocarburizing", "nicarbing", "nitro-cementation", and perhaps by other names. Since exceedingly numerous combinations of alloy being hardened, temperature, time, gas analysis and quench can apply, it is not surprising that different viewpoints have been recorded concerning the commercial value of the process, the properties of the case, and its essential constitution. Practical applications have far outstripped technical understanding. Even today there is little accurate information concerning the iron-nitrogen equilibrium system, let alone the ternary iron-carbon-nitrogen system, so any scientific basis for an understanding of the metallography is missing.

As background it should be mentioned that the process of carbo-nitriding as now practiced has been in use less than 15 years. Actually a patent issued in 1883 had for one of its claims "the process of treating iron or steel in a closed chamber by subjecting the iron or steel to the action of hydrocarbon vapor and nitrogen supplied independently or together in regulated quantities". A recent search of the literature and patents revealed not only the patent mentioned but that the general idea had been investigated by many individuals and companies, but apparently had never been reduced to practice in production-type furnaces.

The background of our own efforts began with the realization that a successful heat treatment of steel without changing its carbon content at the surface required a chemical equilibrium between carbon in the surface layers of the hot steel and the carbon monoxide, carbon dioxide and water vapor in the surrounding furnace atmosphere. We were able to design and construct in 1935 a non-decarburizing furnace for Dodge Motor Car Division of Chrysler Corp. Actually this furnace was able to restore lost carbon in the surface when hardening axle shafts. Subsequently, a gas generator was patented which allowed us to make a gas whose principal constituents were carbon monoxide, hydrogen and nitrogen. By the use of gas from this generator plus a hydrocarbon addition, light case carburizing at 1550° F. became practicable and controllable. We therefore proceeded to install furnaces at Buick in Flint and at Ford's Rouge plant to put a light case on transmission

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gears. These furnaces are still operating; they have an externally heated, alloy muffle; trays are pushed through the muffle and automatically quenched in oil at the discharge end. The gears passed the dynamometer tests set up for cyanided gears, and the furnaces were immediately put into full production.

In comparing the type of case obtained from these furnaces with that obtained from cyanide pots a marked difference was noticeable which we could attribute only to the nitrogen in the cyanide. We therefore added ammonia to our generator and hydrocarbon gas and thus got carbo-nitriding.

Subsequent work in our laboratory showed the usefulness of this process in temperature ranges from 1200 up to 1650° F. and we have built furnaces for operation at various temperatures throughout this range. Further laboratory work showed the possibility of producing a carbo-nitrided case at 1550 to 1600° F. and then (in the same furnace) decreasing the temperature to around 1000 or 1100° F. and quenching from this lower temperature. This process, which we called "quenching below the critical point" is in operation, and permits us to obtain a hard case with an "annealed" core.

Scope of the Process

One difficulty with the name "carbo-nitriding" is that it covers too broad a field. When one mentions gas carburizing, for example, one generally thinks of treating low-carbon steel in a temperature range of 1650 to 1750° F. in such a way that surface carbon concentrations range from 0.90% up to saturated austenite. The term carbo-nitriding, however, is not subject to such close limitations. The material processed in fact may even be cast iron or powder metal compacts, rather than steel. Theoretically it is possible to vary the carburizing and nitriding potential of the gas atmosphere for each temperature within the range of 1200 to 1650° F., thus obtaining a multitude of different types of cases. All may truly be called carbo-nitrided.

We may make a "rule of thumb" division of carbo-nitriding into three separate classes, according to the nature of the work. These are shown in Table I, listed according to their relative importance as

Class 1 — Work requiring case depths of 0.002 in. or more but not falling in Class 2 or Class 3;

Class 2 — Work subject to excessive distortion in heating and liquid quenching;

Class 3 — Work requiring a hard surface and an annealed core.

Considering these briefly in the reverse order, the third classification, "quenching below the critical point", has a rather narrow field of application and its principal use as far as I know has been for heat treating automobile control arms.

The second class is generally used on stampings or pressed metal parts where a light, very wear-resistant case is required and distortion is a problem. Such carbo-nitriding is generally done at temperatures between 1200 and 1450° F. In order to prevent distortion in cooling, these parts usually are not quenched in oil but cooled slowly in a water-cooled jacket attached to the furnace, or blast cooled by circulating a large volume of cold atmosphere through the work. Blast cooling may use fans in the water-cooled section; alternatively some atmosphere gas may be drawn from the cool end of the furnace, passed through a radiation-type cooler, and blown into the cooling chamber. Work falling within this second class requires atmospheres containing fairly large percentages of ammonia and is therefore relatively more expensive than Classes 1 and 3. The type of case obtained resembles that obtained in straight nitriding, although both carbon and nitrogen are added to the steel. It has been used for carbo-nitriding cylinder sleeves, ball caps, thrust washers and other similar parts where case depths of 0.007 in. and less are required.

The first class, done at temperatures above 1450° F., comprises 90% of the work. The balance of this paper will be devoted to this class.

Medium Temperature Carbo-Nitriding

Lower temperatures in the range for Class 1 — that is, 1450 to 1500° F. — will produce cases of 0.002 to 0.003 in. At such temperatures diffusion is relatively slow; consequently, a more uniform light case depth will result when treating dense loads. The reasons back of this will be easily understood if one remembers that at any given temperature the total case depth varies approximately with the square root of the time at heat. For instance, at 1450° F. the total case depth in 1 hr. may be 0.010 in. Half of this would be obtained in 15 min.; a quarter of this (0.0025 in.) would require only 4 min. at heat.

Temperatures of 1500 to 1550° F. are used for heavier cases (0.005 to 0.010 in.) and still higher temperatures for even deeper cases. These temperatures of operation are based on the assumption that a low-carbon steel is being treated and that the core structure is not of primary importance. The quenching temperature necessary for the required core properties in medium-carbon steels will of course narrow this temperature range of operation.

This same consideration — core properties — is what decides the type of quenching medium to

be used — whether caustic, water, soluble oil, or oil. (When the parts have a tendency to distort beyond allowable limits we can use hot oil or hot salt.) Parts have frequently been refrigerated after quenching; sometimes the Rockwell hardness has thus been raised one or more points, but generally the advantage is not worth the extra cost.

Atmosphere Requirements — With this brief account of the effects of temperature and quenching mediums we can now proceed to a brief discussion of the atmosphere requirements. By varying its composition many different types of case structures can be produced. This being so, *control* is necessary, and in this connection a reference to furnace construction is in order.

The carbo-nitriding furnaces in operation today are of the muffle or the radiant-tube type. More recent installations are almost all of the latter. Radiant tubes are either gas fired or electrically heated. The furnaces may be pusher-tray type, rotary, roller hearth, conveyer or batch. Where dense loading is used, fans are installed to insure circulation of the atmosphere gas through the work in order to get uniformity of case.

Regardless of type of furnace, one fundamental requirement must be met and that is that the hot work be surrounded at all times in gas of the correct composition. It is therefore necessary for the furnace to have entrance and exit vestibules attached in a gas-tight manner. If either of these vestibules is omitted, dirty work of variable case composition may be expected. It is also necessary to provide a sufficiently large volume of generator gas to purge the vestibules, to replace losses when outer doors are open, and to provide sufficient furnace pressure to prevent air infiltration. These statements may seem axiomatic but failure to apply these principles accounts for a considerable portion of the unwanted variation in results obtained from commercial equipment.

The 1, 2, 3 of Carbo-Nitriding

Class 1 *Light Case*	Class 2 *No Distortion*	Class 3 *Controlled Core*
	Characteristics	
Work requiring case depths of 0.002 in. or more, but not in Class 2 or 3.	Work otherwise subject to much distortion on heating and cooling.	Work requiring a hard surface and an annealed core.
	Parts Applicable	
Materials formerly liquid cyanided, or liquid carburized, or compound carburized, such as gears, pins, bushings, valve lifters, adding-machine parts, automotive hardware, cams, shafts, washers, spacers, engine parts.	Cylinder sleeves, ball caps, thrust washers, valves and similar items.	Control arms for automobiles.
	Temperature Range	
Medium; 1450 to 1650° F.	Low; 1200 to 1450° F.	Duplex treatment; first a high range (1550 to 1600° F.), then furnace cooled to 1000 to 1100° F.
	Quenching Medium	
Caustic, water, soluble oil, oil, hot oil, hot salt.	Slow cool or blast quench.	Water, soluble oil, or oil.
	Resulting Microstructure	
With low ammonia addition, similar to that from liquid cyaniding. Increasing ammonia increases the amounts of nitrogen in the case.	Similar to nitrided cases, although both carbon and nitrogen are added. A white outer layer is backed up by one or more inner layers. Distinct interfaces are obtained between layers and core.	Case is similar to Type 1; annealed core.
	Rockwell Hardness	
C-57 to 63; file hard.	C-35 to 55 (converted from 15-N scale); file hard.	C-57 to 60 (converted from 15-N scale); file hard.
	Case Depth	
0.002 to 0.035 in.	0.001 to 0.015 in.	0.005 to 0.020 in.
	General Remarks	
Use lower temperatures for light cases; increase temperatures for increased case depths. Vary nitrogen addition by varying ammonia flows. Vary carbon addition by varying CO: CO_2 equilibrium. Ammonia less than 10% of the generator gas usually gives highest hardness and best case.	High ammonia flows are required and careful control of process to prevent formation of a spally case. Properly applied case is very wear resistant, even when showing a low Rockwell hardness.	Very limited field of application.

Any discussion of the relationship between the nature and depth of case on the one hand, and the analysis of carrier gas, proportion of ammonia, time and temperature on the other hand, would be too lengthy for the limitations of one article. As noted in the opening paragraphs, considerable difference in opinion has been expressed. Likewise, several publications have had undue influence when it is remembered that the experimental conditions which those authors used were not representative of commercial practice. Furthermore, the investigator often notes only the composition of the gas streams entering the furnace, whereas the true criterion is of course the composition of the atmosphere in contact with the hot steel parts.

As a result of much laboratory work, published in part in *Metal Progress* in September 1947 and February 1948, supplemented by a dozen years' experience with production, we have concluded that the amount of carbon in the very surface of the steel is the amount which is called for at that temperature by equilibrium between iron and the existing mixture of carburizing gases (such as CO and CH_4) and decarburizing gases (such as CO_2, H_2 and H_2O). In other words, the amount of ammonia or nitrogen in the atmosphere — within limits — does not affect its carburizing action or interfere notably with the diffusion of carbon in the hot steel. That is to say, in carbo-nitrided cases the depth of case and the carbon content at various depths below the surface are what would be expected from a carburized case of equivalent thermal history. However, the thermal decomposition of ammonia, making two volumes from one, rapidly decreases the partial pressures of the other gases considered above when ammonia is used in high percentages. From the equation $K = \frac{(CO)^2}{CO_2}$ it may be seen that if the partial pressure of CO is halved (by dilution), the tolerable amount of CO_2 must be divided by four. This means that if the CO_2 in the furnace is as high as may be permitted, simple dilution of the atmosphere by hydrogen and nitrogen will tend to reduce the carburizing potential.

Two important exceptions should be made here: Nitrogen in solution in iron reduces the critical temperature, so that austenite — and therefore rapid carburization — starts at a lower temperature. Likewise, nitrogen-bearing austenite does not transform to martensite as easily as normal austenite. Quenched carbo-nitrided cases retain more austenite, and while they usually are file-hard, Rockwell hardness may drop noticeably.

The above remarks depend upon the premise that enough carbon and nitrogen is brought into the furnace continually to replace that portion which is absorbed by the steel being treated plus any leakage which may occur. It has been our belief that the optimum amount of ammonia used with a properly controlled carrier gas is considerably less than is being used in many installations. In making this statement we refer to that volume of ammonia required to add the nitrogen content to the case and not to any excess volume which may be used to counteract bad carrier gas conditions. This belief has been difficult to prove satisfactorily until recently, when a rapid and accurate analytical method has been perfected for low amounts of ammonia in the effluent gases. We now have good evidence that the nitrogen in the surface layer of steel increases with the ammonia content of the atmosphere (time, temperature, carrier gas, carbon and depth of the case all being equal). This is not a surprising result, but it is contrary to some published statements.

Another controversial point — or, rather, point of disagreement among students of carbo-nitriding — is the relation between temperature and intensity of nitriding. Everyone will admit that if the furnace is operated at temperatures below what would be the normal critical temperature, the case has the appearance of a nitrided case — a thin, intensely hard, white layer — even though analysis shows that carbon has been added. Nitrogen has lowered the critical temperature for the solution of carbon, but as this temperature is exceeded in the work chamber the case produced has more and more the characteristics of a carburized case and the "white layer" becomes very thin (if it exists at all) without sharp demarcation.

Such undoubted facts have led to the assumption that (in commercial operation with minimum ammonia) the amount of nitrogen absorbed and present in the surface layers decreases with increasing temperatures. This conclusion from practice seems to be verified by scientific work by Messrs. Rengstorff, Bever and Floe at Massachusetts Institute of Technology, reported to the recent annual meeting of the A.S.M. in Chicago. These investigators find X-ray evidence of the nitrogen-rich iron carbo-nitride (epsilon phase) in cases made at 1300° F., but not at 1400 to 1500° F.

To summarize, it may be said that carbo-nitriding is a well-proven commercial process wherein the good characteristics of a cyanided part may be achieved in mass production without the disadvantages of the older cyaniding pot. The interrelation of carbon, nitrogen and temperature on the steel's critical point and the hardenability can be exploited intelligently by the metallurgist to produce parts economically with excellent wear-resistant surfaces, a minimum of distortion, and proper physicals in the core.

Intense radiation, such as exists within a uranium reactor, can be expected to disrupt the crystalline architecture of a metal exposed to it. In this article certain theoretical predictions are checked by experiments on some pure metals and some common alloys, wherein their hardness, modulus of elasticity and electrical resistance are compared, before and after irradiation.

Effect of Nuclear Radiation on Metal*

In a nuclear chain reactor, more popularly known as a "pile", nuclear radiations of several kinds are present — neutrons, γ rays, β particles. The neutron is a fundamental nuclear particle of substantially the same weight as the nucleus of the hydrogen atom but has no electric charge. Gamma rays are electromagnetic waves similar to X-rays, of very high energy and very short wave length; thus the energy of an X-ray of wave length 1 Ångström unit is 12,345 electron-volts, while γ-ray energies are of the order of 2,000,000 ev. (2 Mev.). This energy is very large, because the energy an electron gains in falling through a potential difference of 1 volt (that is, 1 ev.) is equivalent to 23,050 cal. per mole. Beta particles are simply free electrons (elementary particles of negative electricity) moving at high speed and having energies on the order of 1 Mev.

Fission of the uranium isotope U^{235} is of course the fundamental nuclear process in an operating chain reactor. The most important products of the fission process are two highly energetic atoms (fission fragments) each having a mass roughly half of the original U^{235} nucleus, and kinetic energy of the order of 100 Mev. In addition, each fission emits several neutrons of about 2 Mev. energy corresponding to a speed of the order 10^9 cm. per sec. (one thirtieth the speed of light). Most existing reactors are designed in such a way that the neutrons are subsequently slowed down by elastic collisions in each of which they give up a part of their kinetic energy to the atomic nuclei with which they collide. Ultimately, after a large enough number of collisions within the materials of the reactor — so chosen as to be materials which do not *absorb* neutrons — many reach thermal equilibrium with their surroundings whereupon their energy approximates the mean kinetic energy of vibration of the atoms of the solid reactor assembly; if this is at 25° C. this "thermal" energy is about 0.03 ev.

The energy required to knock an atom out of its lattice site in many solids is of the order of 25 ev. It is thus evident that the massive fission fragments having energy near 100,000,000 ev., and neutrons having energy near 2,000,000 ev., have far more than is necessary. The distance in which a fission fragment is stopped — that is, loses all its kinetic energy to the stopping medium — is 10^{-3} cm. or less in solids. In this short distance it gives up 100 Mev., so it is evident that it may displace a great number of atoms and considerably disrupt the material along its path.

On the other hand, an energetic neutron, in elastic collisions with nuclei of substances within the reactor, imparts to these a considerable fraction of its kinetic energy. On the average this is given by a formula for ΔE wherein

$$\Delta E = E_o \frac{2A}{(A+1)^2}$$

E_o being the initial kinetic energy of the neutron and A the atomic weight of the struck nucleus. For a value of $E_o = 2$ Mev., a good average for fission neutrons, a beryllium nucleus (A = 9)

*Edited and styled from U. S. Atomic Energy Commission document AECD-2810, declassified March 22, 1950.

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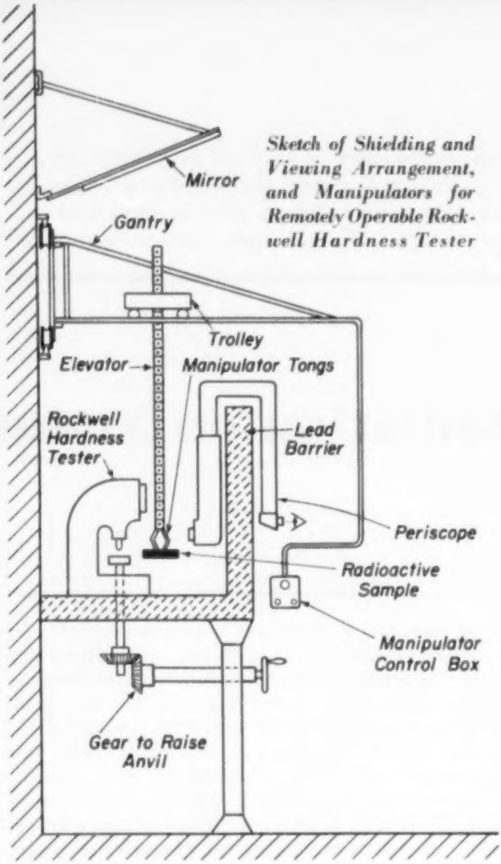

Sketch of Shielding and Viewing Arrangement, and Manipulators for Remotely Operable Rockwell Hardness Tester

receives on the average 180,000 ev., a copper nucleus (A = 64) receives 67,000 ev., a gold nucleus (A = 197) receives 20,000 ev. of kinetic energy as a result of such an elastic collision. This is sufficient to knock the struck atom out of its normal lattice site, leaving behind a lattice vacancy. The displaced atom loses its energy acquired during the impact primarily by exciting electrons of the other atoms it passes along its trajectory through the solid, and (to a smaller extent) by displacing in turn other atoms from the lattice, or by exciting localized lattice vibrations of a mean energy corresponding to a temperature higher than the average temperature of the material.

While the principal process involving fast neutrons is the elastic scattering just described, when the neutrons have been slowed down another process becomes more probable. This is capture of the neutron by the materials in the reactor. Gold, for example, would be about 15 times as likely to capture a slow neutron as to bounce off elastically. Capture of a neutron produces a radioactive isotope, according to the nuclear reaction

$$_0n^1 + {}_{79}Au^{197} \rightarrow {}_{79}Au^{198} \xrightarrow[2.7\text{ days}]{\beta} {}_{80}Hg^{198} \text{ (stable)}$$

showing that the radioactive gold $_{79}Au^{198}$ is unstable and has a half-life of 2.7 days, decaying to Hg^{198}. In this manner a foreign atom is produced in the lattice.

Thus, irradiation of a solid in a reactor can result in displaced atoms, lattice vacancies, localized thermal vibration, and foreign atoms, each one of which theoretically can affect the macroscopic properties of the solid. This paper is a report of experiments testing whether such changes can be measured.

Experimental Methods

The data to be described were obtained in two principal ways. In the first, the properties under investigation were measured on suitably prepared samples before irradiation. The samples were then exposed in a reactor under known conditions of neutron flux and temperature. Finally, the properties were remeasured.

After exposure in the reactor, samples are generally strongly radioactive, and so facilities were developed at the Oak Ridge National Laboratory for taking measurements on samples having an activity as much as 100 curies. (A radioactive material decaying at the rate of 3.7×10^{10} disintegrations per sec. has an activity of 1 curie; this is about the activity of a gram of radium.) Remotely controlled apparatus, situated behind a 5-in. lead barrier, was used. Properties such as dimensional stability, density, electrical and thermal resistivity, elastic modulus, internal friction, hardness, the stress-strain relationship, and others can be measured in this fashion. Equipment for hardness testing is shown at left.

In the second method of experimentation, properties were measured while the sample was situated within the reactor. Such measurements have been restricted to those in which the information can be brought out on electrical leads, and so far have been confined to electrical and thermal resistivity. The Oak Ridge group is developing apparatus for measuring elastic modulus by dynamic means, Hall coefficient (distortion of lines of electrical force by strong magnetic fields perpendicular thereto), and creep while the samples are in the reactor.

A convenient measure of the exposure of a sample is the total number of neutrons which have crossed unit area. The formula for this integrated neutron flux is *nvt*, where *n* is neutron density, *v* is neutron speed and *t* is time. This quantity by itself does not specify the exposure completely, for the distribution in energy of the neutrons is also important. Since the Oak Ridge reactor has a heterogeneous, lattice type of structure, with

uranium rods interspersed in a lattice of graphite, the energy spectrum of the neutrons depends strongly on the local position of the samples with respect to the uranium rods.

Experimental Results

For nonfissionable metals the changes in properties are presumably due only to the effects produced by collisions with fast neutrons of energy high enough to knock an atom out of the lattice. This recoil atom dissipates its energy largely by ionization of other atoms along its trajectory through the solid, and in lesser part by exciting lattice vibrations or in displacing other atoms in turn. Changes in properties of a commercially pure metal may be caused by the displaced atoms which crowd into some interatomic space and thus distort the regular crystalline lattice, by the local regions excessively heated for short times near the recoil trajectory, or by the production of a foreign atom after a neutron-induced transmutation. Neutron bombardment of alloys, on the other hand, may cause metallurgical processes which are otherwise entirely inhibited at the ambient temperature of exposure. Our experiments may be interpreted in the light of the above considerations.

Aluminum — Sensitive experiments on the damping capacity and the density of high-purity single crystals of aluminum were made after an exposure of 2×10^{18} neutrons per sq.cm. in the Oak Ridge reactor. (Damping capacity of single crystals is extraordinarily sensitive to small amounts of cold work.) While an increase in this factor was consistently observed after irradiation, its magnitude was such that it could not be attributed unambiguously to neutron bombardment. No changes in density could be measured.

Copper — Samples of oxygen-free, high-conductivity copper (¼-in. disks, ⅜ in. in diameter) both annealed and cold worked were exposed in the reactor for various times. For short exposures, only the annealed samples were hardened appreciably, from F-36 to F-51. For greater exposures, of the order 5×10^{19} neutrons per sq.cm., both the annealed and cold worked samples showed significant hardening. Annealed samples changed from F-43 to F-90; the samples previously cold worked by swaging changed from F-93 to F-97.

Copper-Gold Alloy* — In a simple metal the displaced atoms will not all remain interstitially stuck in the lattice, for vacancies already existing or produced by the neutron bombardment will diffuse into the neighborhood of such an atom, and it will then fall into a lattice position equivalent to its original one. The equilibrium number of displaced atoms will depend on the neutron flux and on the rate at which vacancies diffuse in the solid; this number may be too small to produce significant changes in macroscopic properties. An order-disorder alloy, however, may show such effects produced by displaced atoms and by increased lattice vibrations even after the displaced atoms have returned to lattice sites, because the degree of order in the lattice may have been changed. This change in order-disorder will be substantially permanent if the experiment is carried out at a temperature below which no changes are observed after ordinary thermal treatment.

A well-known example of order-disorder alloys is Cu_3Au, which can be permanently brought to any state of order by appropriate heat treatment if the temperature is not subsequently raised above about 200° C. Numerous properties, among them the electrical resistivity, depend on the state of order; in the ordered state Cu_3Au has an electrical resistivity at 25° C. of 4.8×10^{-6} ohm-cm.; in the disordered state resistivity is 11.5×10^{-6} ohm-cm.

In our experiments samples analyzing 49.1% copper and 50.8% gold, in the form of ⅛-in. round rods 2¾ in. long, were prepared in the ordered state by slow cooling from 400° C. (750° F.) during 50 hr., and in the disordered state by quenching in water from 550° C. (1020° F.). The samples were exposed at various positions in the pile at 40° C. where the integrated flux per sq.cm. of neutrons with energy above 50,000 ev. was as shown in column 1 of Table I.

It is evident that the electrical resistivity (and presumably the degree of disorder) of the initially well-ordered samples increases with neutron exposure. On the other hand, the resistivity of the initially disordered samples increases by less than 1%; this can be accounted for by the formation, through slow neutron capture, of Hg^{198}, an impurity which raises the resistivity.

Table I — Resistivity* of Cu_3Au Samples Before and After Irradiation

Neutron Flux†	Ordered Samples		Disordered Samples	
	Before	After	Before	After
0.4	4.60	5.71	11.20	11.25
0.6	4.60	6.25	11.20	11.25
1.0	4.60	7.54	11.20	11.17
1.5	4.60	8.36	11.20	11.21
3.3	4.60	10.10	11.20	11.30

*Unit of resistivity: 10^{-6} ohm-cm.
†*nvt* above 50,000 ev. Unit is 10^{19} *n* per sq.cm.

*These experiments have been more fully discussed by Sidney Siegel in "Effect of Neutron Bombardment on Order in the Alloy Cu_3Au", published in *Physical Review*, Vol. 75, June 15, 1949, p. 1823.

Copper-Beryllium Alloys

An alloy containing about 2% Be exhibits striking changes in physical properties as a result of the precipitation-hardening reaction (gradual precipitation of gamma solid solution from a metastable alpha solid solution of beryllium in copper). This produces large increases in hardness and changes other properties — for example, the electrical resistivity. The fact that this reaction does not proceed with any appreciable velocity at or near room temperature makes this particular alloy suitable for these studies.

Our alloy was obtained from the Beryllium Corp. of Pennsylvania; the material had been solution annealed and then cold worked (50% reduction in area). Its nominal analysis was 2.15% Be; 0.2% total Al, Fe, Si; balance Cu. Some data for the high flux density were obtained on samples of a similar alloy containing 0.2% Co.

The usual heat treatments were as follows:

1. Solution anneal: 1 hr. at 1470° F.; quench in cold water.

2. Aging: 1 to 2 hr. at 550 to 600° F.

3. Overaging for various periods up to several hours in the range 660 to 1110° F.

Hardness values reported are an average of at least three readings. Electrical resistivity was measured by the potential drop along a known length of the $\frac{3}{16}$-in. rod through which a known current was flowing; these measurements have an accuracy of ±0.1%. In several instances, dynamic elastic modulus measurements were made on the same rods. Some measurements were made on the width of X-ray diffraction lines.

Electrical Resistance — An examination of the data in Table II shows that the electrical resistance of all samples (regardless of heat treatment) increased upon irradiation. The biggest increases occurred in the solution annealed and in the overaged states (without cold working). A comparison of the relative effect of irradiation on samples which had been cold worked with samples which had not is made in the middle portion of Table II (exposures to 2.3×10^{18} neutrons per sq.cm.).

It should be noted that heat treatments from the solution annealed states show larger increases in resistance for the same heat treatment, also the largest effect occurs in the solution annealed state. (The solution annealed state is the softest state, Rockwell F-14 to 18, while the overaged state is next in order of softness, F-60 plus or minus.)

At the bottom of Table II data are presented for samples subjected to 20 times the exposure. Resistance of all these samples also increased upon irradiation. The increase of resistance in the solution annealed state is not as much as might be expected from the longer exposure, but the overaged samples show an appreciable increase over the samples with shorter exposures.

The electrical resistance was remeasured on the top group of irradiated samples in Table II several times during a six-month period. Values remained constant; thus the effects noted appear to be permanent.

Table II — Effect of Irradiation on Electrical Resistance* of Cu-Be Alloy

Heat Treatment			In Solution Annealed State			Annealed Plus 50% Cold Reduction		
Solution Anneal	Aging							
	Time	Temp.	Initial	Final	Change	Initial	Final	Change
		Exposure: 1.8×10^{18} neutrons per sq.cm.						
1425° F.	—	—	213.8	240.1	+12.3%	229.4	233.2	+1.7%
	1 hr.	570° F.				179.6	181.6	+1.2
	1 hr.	930° F.				130.0	139.3	+7.2
	6 hr.	930° F.				123.1	130.0	+6.3
	10 hr.	930° F.				123.1	130.9	+5.6
		Exposure: 2.3×10^{18} neutrons per sq.cm.						
1425° F.	—	—	211.3	242.9	+15.0%	230.2	234.3	+1.8%
	5 min.	565° F.	212.3	233.7	+10.1	221.2	229.0	+3.5
	15 min.	565° F.	212.6	227.5	+7.1	215.4	220.3	+2.3
	30 min.	565° F.	208.3	214.3	+2.9	203.8	206.4	+1.3
	60 min.	565° F.	170.2	171.2	+0.6			
		Exposure: 4×10^{19} neutrons per sq.cm.						
1475° F.	—	—	234.5	273.4	+15.5%			
	100 min.	480° F.	238.3	251.8	+5.5			
	100 min.	590° F.	200.0	211.5	+5.8			
	240 min.	750° F.	130.0	143.1	+9.4			
	1080 min.	1020° F.	165.3	192.2	+14.5			

*Unit: 10^{-6} ohm-cm.

Hardness — Irradiation at relatively low levels also caused an appreciable increase in the hardness of beryllium-copper in the solution annealed and overaged conditions (Table III), while the cold worked state showed no change, and the properly hardened state showed a slight decrease.

The data in the lower half of Table III are for samples exposed to 50 times the number of neutrons. Hardness increased appreciably, as would be expected. Even the properly hardened samples showed a slight increase, whereas the corresponding sample in the short exposures was softened slightly.

Elastic modulus was

measured both before and after exposure to 4×10^{19} neutrons per sq.cm. The respective changes were +1.6, −0.9, −0.9, −0.6 and +0.5% for the samples listed at the bottom of Table II.

Interpretation of Results

It should be noted here that the effects observed cannot be due to mere heat treatment in the reactor, because its temperature was not over 150° F. More important evidence is in the behavior of the samples themselves. During their normal heat treatment, resistance and hardness do not change in the same direction except for a very slight increase of hardness during the early stages. Thus, for a hardened sample, a temperature effect would act to decrease the resistance, not increase it. An inspection of the initial resistances of the samples listed in Table II will illustrate this point. Furthermore, a thermal effect would be greater on the cold worked sample than on the solution annealed sample. Actually it is just the reverse.

1. The degree of radiation effect is a function of the heat treatment prior to irradiation.

2. The resistance of all samples increases as a result of reactor radiation. All samples increase in hardness if the exposure is long enough.

3. The softer the original alloy the greater the effect of radiation on the hardness and electrical resistance, possibly because the cold worked and hardened samples already contain a high degree of lattice strain, and thus an additional strain is not readily apparent.

4. The more beryllium in alpha solution the greater the effect of irradiation. The solution annealed state contains the most beryllium in alpha solid solution. Furthermore, overaged samples are heated at temperatures higher up on the solubility curve and thus contain more beryllium in solution. This effect can also be seen from the samples in Table II that were exposed to 2.3×10^{18} neutrons per sq.cm. Since increasing the length of time at aging temperature precipitates more beryllium as gamma solid solution, there is less in alpha solution after 60 min. at 565° F. than after 5 min. at 565° F., and the change in resistance is directly related to the amount of beryllium in alpha solution.

5. The effects appear to be permanent. (No decrease in 6 months.)

6. The effects observed may be sensitive functions of the neutron energy, whereas the changes noted did not appear to be proportional to *time* of irradiation. Exposures greater by a factor of 20 do not show a proportionately greater effect on electrical resistance or hardness. This may indicate that the induced changes rapidly approach equilibrium, or it may indicate that the results depend on the location of the samples in the reactor. In one location the proportion of fast neutrons to thermal neutrons is probably much greater than in the other.

7. The maximum hardness obtained by irradiation has not exceeded the hardness obtainable by normal heat treatment. A Rockwell of G-105 is usually considered maximum for this alloy.

8. Preliminary observations on width of X-ray diffraction lines as a function of radiation have been made which indicate that samples in the cold worked or hardened states whose lines are broadened due to the prior treatment exhibit further line broadening as a consequence of irradiation.

9. A 30-sec. immersion in a salt bath at 660° F. removes essentially all the changes in hardness and electrical resistance produced by irradiation. About 75% of the change in resistance is removed after 30 sec. at 570° F., and 30 sec. at 480° F. removed 30% of the change in resistance.

Experiments on Other Alloys

Stainless Steel — Several types of stainless steel were exposed to reactor radiation in the form of hardness disks. The samples were prepared from stock material of A.I.S.I. Types 309, 316 and 347. The samples were irradiated in the "as received" condition, which from hardness measurements indicated that Types 309 and 316 were annealed or hot rolled, while Type 347 had appar-

Table III — Hardening of Irradiated Cu-Be Alloy

Condition No.	Heat Treatment: Prior Treatment	Aging: Time	Aging: Temp.	Hardness, G Scale: Initial	Final	Change
	Exposure: 1.8×10^{18} neutrons per sq.cm.					
1	Quench from 1425° F.	none		14	44	+30
2	No. 1 plus 50% reduction	none		87	87	0
3	No. 2	1 hr.	570° F.	102	100	−2
4	No. 2	1 hr.	930° F.	65	68	+3
5	No. 2	6 hr.	930° F.	55	69	+14
6	No. 2	10 hr.	930° F.	55	71	+16
	Exposure: 9×10^{19} neutro[illegible].cm.					
1	Quench from 1425° F.	none		[illegible]	80	+62
2	No. 1 plus 50% reduction	none		[illegible]	95	+12
3	No. 2	30 min.	545° F.	94	98	+4
4	No. 2	1 hr.	545° F.	101	102	+1
5	No. 2	2 hr.	545° F.	100	103	+3
6	No. 2	3 hr.	545° F.	103	104	+1
7	No. 2	1 hr.	745° F.	89	95	+6
8	No. 2	18 hr.	750° F.	67	85	+18

ently been slightly cold worked. Tests were made on samples of all three types that had subsequently been quenched from 1990° F.

All samples, either as received or solution quenched, were hardened very slightly by exposure to 1.7×10^{18} neutrons per sq.cm. Increases ranged from 1 to 3 numbers on the Rockwell B scale.

More extended irradiation (5.1×10^{19} neutrons) hardened the samples appreciably. Increases were 12, 15 and 9 B-scale numbers for Types 316, 309 and 347 respectively. Extending the irradiation to 8.1×10^{19} caused a further hardening of only one number. Such a slight increase in hardness for a 60% increase in irradiation suggests, as in the copper-beryllium, the possibility of a rapid approach to saturation of neutron bombardment effects.

Monel — Samples of Monel from stock were irradiated under conditions identical with those used for the stainless steel. The results, tabulated in Table IV, are similar to those obtained on other materials. In all cases hardness increased.

Miscellaneous Materials — Hardness measurements were made on other materials such as S.A.E. 4340 steel, brass (63:35), silicon bronze (3% Si, 1% Mn). An increase in hardness was always noted, provided the exposure was great enough.

Discussion of Results

It should be emphasized that these experiments were of an exploratory nature. No attempts were made to monitor the neutron flux accurately, nor to determine the neutron energy spectrum exactly. The samples were chosen as generally interesting examples, but were not studied exhaustively to determine their impurity content, grain size, and other metallurgical characteristics.

Of the two simple metals studied, aluminum and copper, the first showed no significant changes in properties, the second showed significant changes in hardness. These data are not extensive enough, however, to permit valid generalizations which attempt to describe this contrast in behavior.

The observations on Cu_3Au may be discussed in terms of calculations made by the method of Frederick Seitz (*Transactions* of the Faraday Society for April 1949) which estimate the fraction of displaced atoms produced in the integrated flux noted in the first column of Table I. This computed fraction is only a few per cent, and appears too small to account for the nearly complete disordering of the last sample. However, in addition to atomic displacements, elastic collisions can produce lattice vibrations of greater than thermal energy along the track of the recoil atoms, and reasonable estimates show that this excessive temperature along the recoil tracks may reach values of the order of 2200° F. for short periods (of the order of 10^{-10} sec.). These temperature "spikes" produce the effect of highly localized quenches from high temperature, and disorder the lattice in this way. The energy dissipated in exciting elastic vibrations of this type during the exposure appears to be sufficient to account for the disordering observed.

Table IV — Effect of Irradiation on Hardness of Monel Metal

Heat Treatment	Exposure (Neutrons per Sq.Cm.)	Rockwell Scale	Hardness Number		
			Initial	Final	Difference
Cold rolled	1.7×10^{18}	G	79	80	+1
35 min. at 1445° F.	1.7×10^{18}	G	15	41	+26
Cold rolled	5.1×10^{19}	B	98	102	+4
Cold rolled	8.1×10^{19}	B	98	102	+4

However, this hypothesis of localized quenching from high temperature does not adequately account for the behavior of the Cu-Be alloys, wherein the quenched Cu-Be samples (alpha) all exhibit an increase in electrical resistivity, while the disordered Cu_3Au does not. If one considers the results on the entire series of Cu-Be alloys, it does not seem possible to attribute these to precipitation induced by neutron bombardment. The general behavior of the Cu-Be alloys — and, in fact, of the stainless steel and other alloys — seems better described in terms of a localized distortion of the lattice.

The great rapidity with which the radiation-induced hardening of Cu-Be alloys can be annealed-out lends further support to this hypothesis of highly localized distortions.

It is evident from these experiments that exposure of metals to the energetic radiations in a nuclear reactor produces changes in macroscopic properties; these changes depend markedly on the nature of the metal, on its metallurgical state, and on the extent of the exposure. It is evident that many more careful experiments, on such fundamental properties as the crystal structure and its distortion, energy stored in the lattice, effects of temperature of exposure, and effects of annealing subsequent to exposure, are necessary before clear interpretations of the effects we have observed can be made.

Tools may either warp or change volume while they are being heat treated. The author discusses effects of steel composition, quenching medium and tool shape. He tells how to predict the amount of distortion and how to minimize it in practical heat treatment.

Distortion of Toolsteel in Heat Treatment

THE TERM distortion, as applied to toolsteel, is used to describe a change in shape or size of a tool as a result of heat treatment operations used to harden the tool. Distortion may be considered as being made up of two components: *(a)* warpage, which is change in shape with no change in volume of the tool, and *(b)* growth (or shrinkage), which is an increase (or decrease) of external dimensions resulting from the volume changes caused by hardening.

The warpage factor is usually associated with the geometrical shape of the tools and with thermal stresses produced by nonuniformity of heating or cooling operations. It is practically independent of the composition of the toolsteels.

Growth or shrinkage is often called inherent distortion; it is a characteristic of each grade or composition of steel and varies considerably with the composition. The inherent distortion is a constant factor only when the heat treatment operations are specifically defined; variations in heat treatment can produce enormous variations in so-called inherent distortion of a given grade.

Following are some typical approximate inherent distortion "factors" which are commonly used in connection with hardening of toolsteel:

1. Carbon toolsteel — 0.002 to 0.004 in. per in. (plus).
2. Manganese oil hardening steel — 0.0015 in. per in. (plus).
3. Air hardening steel (5% Cr) — 0.001 in. per in. (plus).
4. High-carbon high-chromium steel — 0.0005 in. per in. (plus or minus).

These factors cannot ordinarily be used to predict distortion with any degree of accuracy, except in spherical objects. A more precise method of studying inherent distortion characteristics is to measure the specific gravity of the steel before and after hardening. From such measurements, volume changes in going from the annealed to the hardened state can be calculated. Typical data are shown in Table I, page 854.

Although these data are more exact than the "factors", they still do not provide information which will be of practical aid in predicting distortion of tools in heat treatment, except under certain specific conditions.

Before attempting to explain how to predict the distortion which may be expected to occur in a given tool, it may be well to review five fundamental facts concerning toolsteel:

1. Steels expand when heated and contract when cooled. However, when passing through their transformation ranges, the reverse is true.
2. Cold steel is strong; hot steel is weak. It is therefore obvious that during liquid quenching operations, where great temperature differentials occur, the cold steel will "stay put", while the hot steel will deform in response to stresses set up by the temperature differentials. The resulting deformation is often called warpage, and is sometimes called hot upsetting.

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3. Martensite occupies a greater volume than the soft steel from which it came. In other words, the hardening of toolsteel normally produces expansion.

4. Austenite occupies a smaller volume at room temperature than the annealed steel from which it came. Thus, the more austenite retained after quenching, the less will be the expansion due to martensite formation.

5. Some types of toolsteel are shallow hardening; that is, they harden fully only in the outer layers; the inner portions do not transform to martensite during hardening and thus are unhardened. The term shallow hardening is relative, as the size of the section involved determines whether a given steel will harden through or not.

In order to understand how the above facts may be of value in predicting distortion, it is necessary to appreciate the fact that distortion is the sum total of the effects of warpage plus the effects of inherent distortion. If these two effects are additive, a large amount of distortion will be noted; if they oppose each other, the amount of distortion may be negligible. The relative effects of warpage versus inherent distortion may best be considered by dividing the toolsteel grades into groups, classified by the type of quenching medium needed for hardening.

Types of Quenching

Water Quenching — The data in Table I indicate that water hardening carbon toolsteel expands considerably during hardening, as a result of inherent distortion, if the section is small enough so that through hardening occurs. (A volume change of 0.9% corresponds to 0.003 in. per in. length change.) When the section is large enough to be shallow hardening, the expansion is considerably less, and is in the range of values shown for oil hardening steels. Since most applications of carbon toolsteel involve sizes which do not harden through, it may logically be asked why tools made of this steel distort so much more than other steels. The answer to this question is that inherent distortion plays only a minor part in the distortion of water hardening carbon toolsteel; the major part is played by warpage (hot upsetting, or the action of cold steel upon hot steel). Warpage is large because of the large temperature gradients in tools during water quenching. The warpage factor is, to a large degree, controlled by the size and shape of the tool, since the geometry of the tool determines which portions will cool first in a quench and which will cool last.

It is a recognized fact that steels such as carbon toolsteel, which require water quenching for hardening, are notoriously treacherous with respect to distortion. If a number of identical tools are made up from carbon toolsteel and are heat treated exactly alike, it will be found that, after hardening, each tool is of different size and shape. This is due to the nonuniformity of cooling in the quench because of vapor pockets which form on the surface of the tool during quenching. Thus there is a variation in the warpage factor on each tool.

Unfortunately no method exists for evaluating the warpage factor. We are, therefore, unable to predict the distortion of water hardening carbon toolsteel except in a general way on the basis of previous experience with tools of similar size, mass and shape.

As an example of the unpredictability of distortion of water hardening carbon toolsteel, consider the die shown in Fig. 1.* If a die of this type is made up from carbon toolsteel, it will be found that the dimensional changes resulting from hardening are less than 0.001 in. per in. except on the thickness, which is better than the results which can be obtained from most air hardening toolsteels. The explanation of this result must be that the distorting tendency resulting from warpage counterbalances the inherent distortion, and the volume change resulting from hardening appears entirely as an increase in the thickness.

*Development of this shape as a test piece for distortion is due to A. W. Barndt of Heintz Mfg. Co.

Table I — Volume Changes in Hardening Toolsteel

Grade of Steel	Size of Specimen	Specific Gravity, Annealed	Hardening Treatment	Specific Gravity, Hardened	Volume Change in Hardening
Carbon toolsteel	⅜ dia. x 1⅛ in.	7.865	1450° F.; brine	7.795	+0.9%
Carbon toolsteel	1⅛ dia. x 3	7.835	1450° F.; brine	7.800	+0.5%
Carbon toolsteel	½-in. wafer cut from center of 1⅛ dia. x 3-in. piece after hardening	7.855	1450° F.; brine	7.835	+0.3%
Mn oil hardening	½ sq. x 1 in.	7.853	1475° F.; oil	7.805	+0.6%
Si-Mn shock resisting	½ sq. x 1	7.770	1625° F.; oil	7.725	+0.6%
Air hardening (5% Cr)	½ sq. x 1	7.815	1775° F.; air	7.795	+0.3%
High-C, high-Cr	½ sq. x 1	7.710	1850° F.; air	7.715	−0.1%

Air Hardening Steels — Because of the small temperature gradients which exist in most tools during cooling in still air, the warpage factor is practically negligible in air hardening steels. Under these conditions distortion may be quite accurately predicted using only the inherent distortion factors. However, tools which have considerable variation in section, or those cooled in an air blast, will not cool uniformly, and thus the warpage introduced will affect the distortion.

Oil Hardening Steels — Oil quenched tools have temperature gradients larger than those present in air quenched tools but not nearly so large as those present in water quenched tools. Oil quenching does not produce vapor pockets, as water quenching does, and therefore the size changes which occur in oil quenched steels are reasonably consistent on duplicate tools. Generally, the warpage effects in oil quenched tools are considerably less than the effects of inherent distortion if the section involved hardens completely through. Therefore, inherent distortion factors can be used as an approximation of expected distortion of oil quenched steels, although the accuracy of such predictions will not be so good as on air quenched tools. If the tools do not harden through, the use of inherent distortion factors will be extremely misleading, and distortion cannot be predicted except on the basis of previous experience.

Oil Hardening Steels Quenched in Salt — Quenching of tools in molten salt (martempering) involves smaller temperature gradients than oil quenching, and thus serves practically to eliminate the warpage factor in steels normally hardened by oil quenching. Therefore, the distortion of salt quenched tools can be quite accurately predicted by use of inherent distortion factors.

The application of the five fundamental facts will now be considered with regard to tools of different shapes.

Effect of Shape

Cylinders — In hardening cylindrical objects of sizes where the diameter and length are both small, it is invariably found that both the length and diameter expand as a result of the hardening operation, simply because of comparatively uniform martensite formation.

In a shallow hardening steel, if a cylindrical part of length considerably greater than the diameter is hardened by vertical quenching (as it always should be), it is practically always found that the diameter increases, but the length contracts. The reason for this will be apparent if the hardening operation is visualized as follows:

1. As the first portion of the cylinder is hardened, the end face and the circumference tend to expand.
2. As additional sections of the circumference harden, the outer cylindrical surface expands and tries to take the hot interior with it.
3. In order that the hot interior can expand with the outer surface, hot center metal is "sucked in" longitudinally from the as yet unhardened steel, thereby contracting the length considerably before the upper face end can be hardened.

In view of the actions described in the preceding two paragraphs, it should be apparent that there is a certain size of cylinder, for a given steel and set of quenching conditions, which will not change length at all in the hardening operation. When the above conditions are determined, it is universally true that an increase in the length of this cylinder will result in contraction of the length in hardening; conversely a decrease in the length will result in expansion of the length in hardening. However, when working with a deep hardening steel, expansion in all directions will usually occur, to a degree indicated by inherent distortion factors.

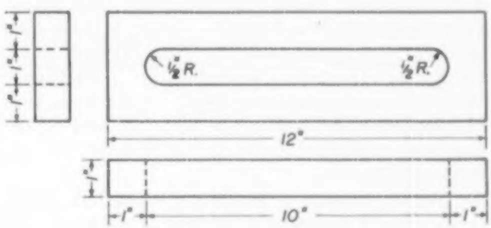


Fig. 1 — Die Used as a Test Piece for Distortion. Developed by A. W. Barndt

Long Rectangular Shapes — As an actual example of how shallow versus deep hardening will affect long tools, consider the hardening of two shear blades about 1 x 4 x 120.000 in. and 2½ x 6 x 120.000 in. made of a silicon-manganese shock-resisting steel. After hardening to Rockwell C-58, it will be found that the 1 x 4-in. blade will be about 120.250 in. long while the 2½ x 6-in. blade will be 119.875 in. long. The thin blade hardens through, and thus expands in all directions because of martensite formation. The thick blade does not harden through and contracts in length by the mechanism just described for long cylinders.

Short Rectangular Shapes — Generally, short rectangular solid dies will expand in all directions as a result of the hardening operation if the section hardens completely through. On air hardening steels, the amount of expansion can be accurately predicted using the inherent distortion factors. For oil hardening steels, the amount of expansion

Table II — Distortion of Manganese Oil Hardening Steel Die

	Before Treatment (Annealed)	After Hardening Treatment*	Size Change	
		Small Die		
Length	5.7688 in.	5.7720 in.	0.0032 in.	+0.0006 in. per in.
Width	1.7501	1.7542	0.0041	+0.0023
Thickness	1.3760	1.3796	0.0036	+0.0026
		Large Die		
Length	11.5010	11.4890	−0.0120	−0.0010
Width	5.5004	5.5147	+0.0143	+0.0026
Thickness	2.2506	2.2574	+0.0068	+0.0030

*1475° F.; oil quench; 400° F. temper.

can be *estimated,* if too great accuracy is not expected. The example in Table II will illustrate this point; it was selected to show the amount of error which may ordinarily be encountered in predicting size changes in oil hardening steels. The change in volume of the small die is 0.55%, which corresponds to an average linear change of 0.00175 in. per in. The position may well be taken that the actual change in inches per inch is not very close to the linear factor. However, with each dimension expanding 0.003 to 0.004 in., the "cleaning up" of this die is a simple matter. The variation in these results from those predicted by use of inherent distortion factors is a measure of the degree to which warpage has influenced the distortion of the die.

As an example of the errors which can result from misuse of inherent distortion factors, consider the second set of data in Table II, showing the distortion of a die about twice the size of the first one. The increase in volume of this die is 0.46% — lower than normally expected for this grade, and indicates that the die did not harden completely through, thus accounting for the decrease in length. It is obvious that inherent distortion factors cannot help in predicting distortion of a die of this type.

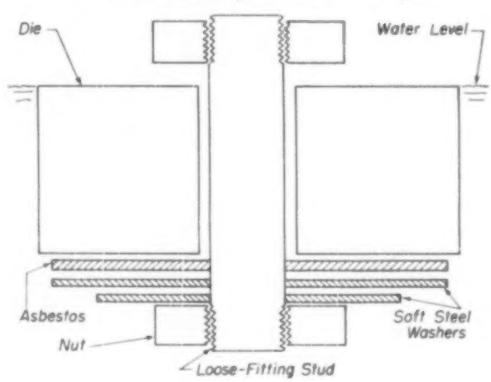
Ring Dies — As a further example of the use of the basic principles outlined, consider the hardening of a ring die. It is common knowledge that a heat treater "shrinks the bore" of ring dies in heat treatment by quenching through the bore. This may seem inconsistent with previous statements, wherein it is pointed out that the formation of martensite by quenching always causes expansion. Further consideration will show that this is not inconsistent, since the over-all contraction is actually caused by the expansion due to martensite formation. If the hardening of each segment of a ring is visualized, it can be seen that the ring will expand at the bore surface. However, the net effect of expansion at the bore surface actually results in contraction of the bore diameter. Another way to visualize this action is to realize that the diametrical expansion of a bar will occur whether the bar is straight or "rolled up" in the shape of a closed ring.

When a ring die is quenched all over, the outside diameter will invariably increase, while the inside diameter may move slightly in either direction, depending on the relative dimensions of the die. If a ring is thin in comparison to wall thickness, the hardening of the faces will control the net distortion due to their relatively greater area presented to the quench. This type of ring will increase in thickness and will usually decrease in outside diameter and increase in inside diameter. If the hole in a die is so small that effective quenching through the hole cannot occur, or if the hole is packed to prevent quenching in the bore, the hole will enlarge due to the fact that it "goes along" with the rest of the die in its expansion due to martensite formation.

Ring dies made of air hardening steels will enlarge in both outside and inside diameters in amounts calculated from inherent distortion factors. However, if it is desired to have the bore close in, this can be accomplished by air blast quenching through the bore.

There is another application of the basic principles which is in common use for shrinking the bore of ring dies. The bore of a ring die can be "closed in" about 0.002 to 0.003 in. per in. of bore diameter by this method, which involves:

Fig. 2 — Sectional View of Apparatus for Shrinking the Bore of a Ring Die. The central bolt assembly must be water-tight



(a) heating the die uniformly to approximately 1800° F., *(b)* quenching the die, on the rim only, to 500° F., while avoiding a quench in the bore (see Fig. 2 for a sketch of the apparatus used in this step), *(c)* reheating to the proper hardening temperature, and *(d)* quenching through the bore only, while avoiding a quench on the rim.

The explanation of how this method works is that *(a)* the quench on the rim causes the metal in this location to contract, thus "hot upsetting" or warping the adjacent hot metal toward the bore; *(b)* stopping the quench at 500° F. does not permit the formation of martensite and thus does not set up any opposition to the contraction forces; and *(c)* the subsequent quench through the bore further contracts the bore diameter by the inward expansion resulting from martensite formation.

Other Factors

Predictions are further complicated by other factors, the most important of which are scaling, variation in quenching, and tempering.

Scaling — In most commercial heat treating equipment, it is found that steels will scale during heating for the quench. The loss of metal due to scaling cannot be ignored since the loss is in the same order of magnitude as the size changes resulting from heat treatment. In some instances, the scaling is an advantage from the distortion viewpoint since it tends to counterbalance expansion which occurs in hardening. (Of course it will likewise increase the magnitude of shrinkage which might occur.) As a matter of fact, the great reputation of the manganese oil hardening type of toolsteel as a "nondeforming" steel is to some degree based on the fact that scaling, which occurs in heating for hardening, almost counteracts the expansion which most often occurs during hardening of this grade. Therefore, in new furnaces which prevent scaling, toolsteels may appear to expand more than when treated in older equipment. Also, it should be recognized that salt baths usually do not prevent scaling, although they appear to do so. Actually, scaling occurs but the scale is dissolved by the salt so that it is not visible. However, the short holding time in salt baths helps to reduce the loss due to scale.

Variation in Quenching — Variation of quenching temperature, either above or below the recommended range, will usually have a pronounced effect on distortion. In general, high temperatures tend to promote retention of austenite, which may decrease the expected expansion or increase shrinkage; lower temperatures promote more complete martensite formation with accompanying increase in expansion. Other factors in the quench, such as temperature and viscosity of quench and degree of agitation, will also affect distortion insofar as they affect the completeness of the austenite-martensite transformation.

Tempering — Fundamentally, the tempering operation causes decomposition of martensite and, in the hardened toolsteel, would be expected to counteract some of the expansion resulting from martensite formation. This effect is actually noted in most toolsteels to an appreciable extent. Table III shows the amount of volume change produced by a 400° F. temper on some typical steels.

Table III — Volume Changes in Tempering Toolsteel at 400° F.

Grade of Steel	Specific Gravity, Annealed	Specific Gravity, Hardened (See Table I)	Specific Gravity, Hardened and Tempered	Volume Change in Hardening	Volume Change in Hardening and Tempering
Carbon toolsteel (⅝ dia. x 1⅝ in.)	7.865	7.795	7.805	+0.9%	+0.8%
Mn oil hardening	7.853	7.805	7.818	+0.6%	+0.45%
Si-Mn shock resisting	7.770	7.725	7.730	+0.6%	+0.5%
Air hardening (5% Cr)	7.815	7.795	7.800	+0.3%	+0.2%

Due to the fact that it is unsafe to measure tools, particularly liquid quenched tools, in the as-quenched condition, the distortion is usually measured only after tempering. The inherent distortion factors usually have been corrected for the size changes produced by tempering, and thus can be used directly in predicting size changes from the annealed state to the tempered state.

The use of progressively higher tempering temperatures will eventually eliminate the size changes resulting from inherent distortion but at that point the tool will have lost all the hardness produced by quenching and the structure will consist of ferrite and carbide, as in the annealed condition. Thus, this method is of no practical value.

In discussing change of size of tools resulting from hardening, it is common practice to measure

a given dimension at a certain location. However, if a given dimension is measured at a number of locations, variations of appreciable magnitude will be found. For example, holes in dies may become "hour-glass" in shape, or may "belly" in the interior. Thus the recorded diameter of the hole will depend on where the hole is measured. For the utmost in precision it is necessary to measure all basic dimensions in a number of locations. Measurement of a few dimensions may not give a true picture of distortion.

Rehardening of Tools

Tools are often rehardened by first annealing the hardened tool, followed by requenching and retempering. Distortion in the original hardening operation which resulted from inherent distortion will be removed by the anneal, but the distortion resulting from warpage will not be removed and will reoccur a second time in the second hardening operation. Thus, a tool which shrank 0.010 in. on one dimension as a result of the warpage factor associated with its size and shape will shrink the same amount on the second treatment, making a total shrinkage in two treatments of 0.020 in.

Minimizing Distortion

At this point in our discussion, it should be obvious that there is no toolsteel which can be hardened without distortion, despite the amounts of so-called "nondeforming" and "nondistorting" steels which have been sold and used. Since a volume change always accompanies the hardening operation, it is fundamental that there must be dimensional changes. Occasionally certain tools will be heat treated with negligible distortion and the assumption will be made that the particular grade of steel used is free from distortion. However, if a tool of different size and shape is made up, the size stability seems no longer to exist.

A commonly used distortion test piece is a cylindrical specimen of small diameter and length. As previously mentioned, it is possible to determine the dimensions of a cylindrical specimen which will not change length at all during heat treatment. Thus, cylindrical specimens, depending upon the dimensions chosen, may give a very optimistic viewpoint concerning the freedom from distortion of a given steel. If this information is used in connection with pieces of dimensions similar to those of the test piece, it will be very helpful in predicting and controlling distortion; if the information is applied to pieces of different size and shape than the test piece, it will be misleading.

Although there are no nondistorting steels in the quantitative sense of the word, it is possible with one grade of toolsteel, high-carbon high-chromium, to obtain zero distortion on at least one dimension of a tool by proper control of the heat treatment operation. The method of control involves balancing shrinkage produced by austenite formation against expansion produced by martensite formation and is performed as follows:

1. Heat the steel to 1850° F.; hold 1 to 3 hr. for carbide solution.
2. Air cool (quench) to 150° F. or less. Normally, tools are tempered immediately upon reaching 150° F., but on most tools made of this type of steel, it is safe to cool to room temperature.
3. Measurement of the tools will show that external dimensions have contracted approximately 0.0005 in. per in. as a result of austenite retained in the quench (air cool).
4. Temper at 920° F. and air cool. In some instances the tempering will cause some of the austenite to transform to martensite, and the expansion resulting from the formation of martensite will neutralize the original shrinkage produced in the quench.
5. If the 920° F. temper does not completely neutralize the shrinkage, the tools are retempered at 930° F. to produce the desired expansion, or successively at 940 or 950° F., or even higher, if required. If the tempering increment is properly chosen, it is possible to bring at least one dimension, and usually more, back to exactly zero size change.

It is not possible to specify a more definite tempering procedure because the tempering temperature required to produce the desired amount of martensitic expansion depends on the exact austenitizing conditions used in heating for the quench. The temperature attained by the tools (not by the thermocouple) and the time the tools are at temperature (not the time the thermocouple is at temperature) directly control the amount of austenite retained in the quench. The temperature and the time will depend on the amount of steel charged in the furnace, the thermal "head" or heating capacity of the furnace, the atmosphere in the furnace, and other variables, so that the exact austenitizing procedure to be used in this method must be developed with the equipment to be used in production heat treating. A heat treater who is familiar with his equipment and this type of steel will rarely require more than two tempering operations to accomplish the desired end. This method of controlling size change has been in practical use for about ten years.

Following are some additional notes of interest in connection with this method:

1. If shrinkage is not produced in the quench, it usually will be impossible to correct the size changes by tempering.
2. At the point of zero size change, peak hardness of approximately Rockwell C-60 is obtained.
3. High tempering temperatures should not be

used on the first temper. If conditions were such that 920 or 930° F. would have sufficed, the higher temper will produce expansion beyond that desired so that the piece is permanently expanded. The high temper will also cause loss of peak hardness.

4. If an excessively high quenching temperature or an unusually long hold at temperature is employed, an unusually large amount of austenite will be retained in the quench. This may require the use of unusually high tempering temperatures (as high as 1050° F.) in order to obtain the desired expansion.

5. For maximum toughness and resistance to grinding checks, it is advisable to double temper, the second temper being at 900° F., or 25° lower than the temperature used for martensite transformation.

There is one other characteristic of high-carbon high-chromium steel regarding distortion which must be mentioned. As pointed out by Howard Scott and T. H. Gray (A.S.M. *Transactions*, Vol. 29, 1941, p. 503), the distortion of this type of steel in the longitudinal direction is about twice as great as in the transverse direction. It is for this reason that dies, where exact thickness is unimportant, are cut from the bar stock so that the thickness is in the longitudinal direction if this is consistent with the direction selected on the basis of intended working stresses. While the size change in hardening with respect to the longitudinal direction can be controlled by the austenite-martensite balance method, for precision work it is necessary to recognize the difference in movement of this steel in longitudinal and transverse directions. Generally, an austenitizing temperature higher than 1850° F. is required, in order to obtain the initial shrinkage in the longitudinal direction. This shrinkage can be neutralized in exactly the same manner as outlined previously. However, when zero size change is obtained in the longitudinal direction, the transverse dimensions will usually show some expansion.

Summary

The practical control of distortion of toolsteel in hardening can be carried out as follows:

Tools on which little or no metal is to be removed by grinding after hardening — Tools in this class require the use of a good controlled atmosphere furnace to avoid scaling and soft skin (decarburization) which must be removed.

1. Use high-carbon high-chromium toolsteel and heat treat for zero size change on the critical dimensions by the austenite-martensite balance method described in the text. A small amount of grinding may be required on the less critical dimensions, if it is desired to bring all dimensions back to zero size change.

2. Use an air hardening toolsteel, such as the 5% Cr type, allowing for the expected expansion which will occur in the hardening operation. The usual allowance for this type of steel is 0.001 in. per in., but a more accurate allowance is 0.0007 in. per in.

3. The required accuracy cannot ordinarily be obtained with oil or water quenching steels, except on the basis of previous experience with tools of the same size and shape.

Tools on which an allowance for grinding must be made in order to remove surface sçale and soft skin — Tools which are heat treated in furnaces not equipped with atmosphere control will develop a certain amount of scale and decarburization which must be removed by grinding to produce satisfactory working surfaces. While this grinding operation is being carried out, it is a simple matter to do a small additional amount of grinding to produce the desired dimensions.

1. When using air hardening steels, the first two methods outlined immediately above will provide more precision than is actually needed for proper control.

2. When using oil hardening steels, in sections which will harden through, the proper allowances can be made on the basis of inherent distortion factors. The allowance for manganese oil hardening steel is 0.0015 in. per in., and about 0.002 in. per in. for other oil hardening steels.

3. When using water hardening steels, or oil hardening steels in sections which do not harden through, proper allowances for distortion in hardening can be made only on the basis of previous experience with tools of the same size and shape.

Fig. 3 — Long and Spindly Parts Should Be Hung Vertically. Photo Courtesy Cincinnati Milling Machine Co.

Critical Points

By The Editor

Railway Cars in Production

STEELMAKERS are fond of calling theirs a "feast or a famine industry", as well they might in view of operations ranging from 98% of capacity in 1943 to 20% of capacity in 1932. However, they must give the freight car builders title to the slogan. Thirty cars were ordered in the month of April 1949; 30,000 in July of 1950! Today the railroads are clamoring for cars in such number as to require capacity operations for a year. The difficulty of getting necessary materials promptly from suppliers already booked to capacity with orders from steady customers is eased by an allocation order from the National Production Authority. It would seem to an outsider unfamiliar with the railroad industry's inhibitions, that the American railroads, with half their 1,750,000 freight cars already obsolete (that is, over 20 years old) could set up an orderly replacement program that would insure steady shop operations at minimum economical production rates, at least. It would save them a considerable amount per car in extra costs of recruiting and training workmen for short campaigns.

That, at least, was apparent to the Editor during a day-long inspection of Pullman-Standard Car Mfg. Co.'s plant at Michigan City. Here freight cars were first made in 1880 by Haskell & Barker, largely (aside from wheels and couplers) of wrought iron and timber. Wooden box cars persisted until the World War I era; methods of straight-line production established over 50 years ago still exist — in fact, are so common that the capacity of the various plants is measured in their "tracks".

If a car moves from station to station every 20 min. the capacity of the track is 24 cars per 8-hr. day, or about 6000 cars per year. (The entire industry, including the railways' own car shops, has 22 lines and thus can make about 130,000 freight cars a year in single-shift operation.) Of course a track can be twice as long and the cars under construction move up every 10 min., but this does not affect the daily output, since only half as much work is done at each station. Apparently, tradition and the union rules prevent a speed-up to, say, 9-min. intervals.

Work at each station is done by men working in pairs — or by two or four pairs. This is due to the nature of the tasks, such as work at each end of a long beam, or a riveting or a bolting team (one man inside, his partner outside the car). Likewise the individual units and small subassemblies are usually too heavy for one man to handle. Work at each station is therefore done by specialists and their movements are beautifully coordinated. However, the result of such specialization into unit jobs in unit time is that a line must operate at a certain rate or not at all.

The minimum production rate would be fixed by the ability of the individual crews to take on the allied jobs immediately before and after their normal stations, and the storage facilities for the product of such heavy equipment as flanging presses which would then operate perhaps one week a month.

There are other factors that militate against the perfection of mass production methods instituted 50 or 60 years ago. Aside from the sporadic placement of orders is the variability in the cars that *are* ordered. Anyone can think of box cars, gondolas, hopper bottoms, flat cars, refrigerator cars and tank cars. That only is the start of it. Even today, each railroad seems to have its own ideas of how many gadgets a box car should carry; furthermore the railroad equipment industry is a happy hunting ground for vigorously promoted specialties. There are trucks and bolsters, there are car ends and doors, roofs and sides — each patented, each manufactured by its promoter, all in such variation that the car builder became primarily an assembler. At Michigan City,

Pullman is endeavoring to improve this situation by manufacturing a standardized box car, the result of sound design, welded construction and optimum use of materials. Its excellence has been proven by full-scale tests of the most shattering type as well as by years of experience in service. Acceptance of some such standardized design by the railroads (and by equipment trusts which own rolling stock and lease it to the roads) seems fundamental to any real improvement in production rates in the building of freight cars.

Today's Magnesium

Accepting an invitation from an old friend, Arthur Winston, currently president of the Magnesium Association, to give a luncheon talk on "Metals of Tomorrow", the Editor found the members much more interested in knowing what Uncle Sam intends to do with the magnesium that can be made in 1951, yet those same men baffled by the uninformative replies to pertinent questions given by representatives of the National Production Authority, Ordnance, and the U. S. Air Forces. It is known, for example, that about two thirds of the 25,000 tons of ingot metal which Dow Chemical Co. (the only private producer in the United States) can produce annually is now going into articles for civilian consumption, and one third of it into military orders. Orders for the latter are increasing at such a rate as to suggest that *all* of Dow's product will be used for aircraft engine parts and ordnance items in 1951 — not a bright outlook for a young industry which in four years has made a substantial beginning in establishing civilian uses against strong competition and which believes that civilian consumption is the only permanent basis for growth. It is known that the wraps are now being taken off several of Uncle Sam's ingot plants shut down since the war and metal will start trickling out of them by spring. When all these are operating, some 100,000 more tons of ingot will be made annually (four times Dow's production) but here's the rub — this metal is apparently allocated to the "strategic" stockpile rather than to aircraft production! Why magnesium should be classed as a "strategic" metal (like tin and manganese) is beyond comprehension when there is unlimited raw material within our borders and ingot capacity in operating or in stand-by condition capable of producing at half the peak achieved during World War II . . . . . . Currently, the industry has voluntarily arranged to divide the available ingot between military and civilian orders in the ratio of one to two. About one third of this magnesium is being put into wrought products, another third into castings, and the remainder used for alloying and chemical reagents. Increase in rolling capacity for plate and sheet cannot be expected before Dow's new mill is ready in 1952. Foundry capacity can be expanded somewhat more rapidly, what with the skills acquired during the last war, but no one seemed to know how much tonnage in castings would be needed next year, let alone what proportion would be relatively simple pieces and what proportion would be highly complicated jet engine casings. Snafu!

Metals of Tomorrow

As for "Metals of Tomorrow", the Editor made the conservative guess that they would be based on our common metals of today, at least as far as structures and machines are concerned. The common metals like iron, aluminum and magnesium (and possibly titanium, the newcomer) will continually grow in relative consumption as compared with the scarcer metals like copper, zinc, lead and mercury. Alloying metals, by the same token, will become more important; the ones now well known will be joined by others now little more than chemical curiosities. Especially important will be the refractory metals and their compounds for uses at high temperature. Number and variety of alloys with special properties competing for specific uses will increase almost without limit and their success — survival, even — will depend on economics and their engineering properties. Overtopping all this, of course, is the emergence of the heaviest metals, thorium, uranium and plutonium, in the field of power both industrial and political. . . . . . It will be a great life, you metallurgists of tomorrow!

The Case of Prof. Dr. Guertler

Hugo Krause, editor of the German journal *Metalloberfläche*, writes that Prof. Wilhelm M. Guertler (remembered as the first of the Campbell Memorial Lecturers) "is living in the Soviet zone of Berlin under truly heart-rending conditions. He, with two children who still go to school, is compelled to live on a 'social security' pension of 170 Ostmark per month, which is slightly more than $5.00."

Dr. Guertler's address is Falkenried 27-29, Berlin-Dahlem, Germany. CARE (20 Broad St., New York City) is able to guarantee delivery of gift packages to all of Berlin, including the Russian sector.

In Metal Progress *for August, Messrs. Maltz and DePierre dealt with the forging of commercial titanium containing 0.78% carbon. Metallography and heat treatment of the same material are discussed here.*

Heat Treatment and Structure of Commercial Titanium

By Joseph Maltz and Vincent DePierre
Metallurgists, U. S. Naval Gun Factory
Washington, D. C.

METALLOGRAPHIC TECHNIQUES for titanium have recently been described by Finlay, Resketo and Vordahl (*Industrial and Engineering Chemistry*, February 1950). The authors will merely add some of their own observations.

There are three principal difficulties in the metallographic polishing of titanium.

1. Formation of mechanical twins during cutting-off operations. This characteristic of titanium, while probably not quite so bothersome in the commercial alloy as in high-purity metal, can be responsible for a bewildering array of artifacts.

2. Flow of a thin layer of alpha titanium over the carbides during grinding on the finer abrasive papers. The effects of this can be confusing. After a few seconds on the intermediate polishing lap (600-grit silicon carbide on canvas), the carbides seem to be overpolished and pulled out; but continued polishing brings out their outlines in satisfactory fashion. Figure 1 illustrates this phenomenon.

3. Piling up of disturbed metal around each carbide particle, which stands in relief above the matrix material. It is caused by excessive pressure or excessive time on the polishing laps, and the use of soft-napped polishing cloths. The disturbed metal can be removed by prolonged polishing with

After 4/0 Paper | 15 Sec. First Wheel | 1 Min. First Wheel | 3 Min. First Wheel

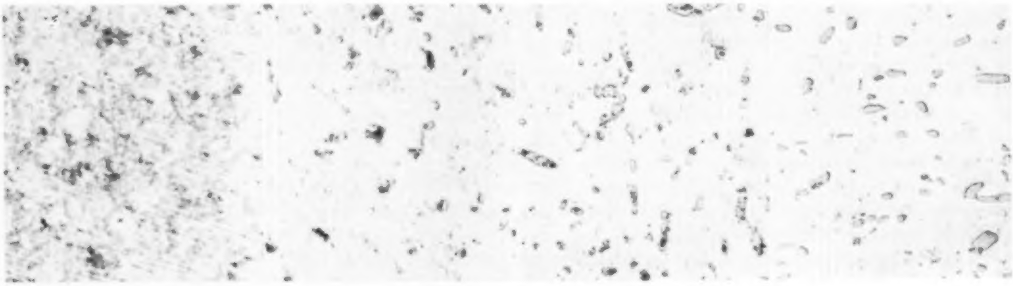


Fig. 1 — Improvement in Carbide Delineation With Increasing Time on First Polishing Wheel (600-Grit Silicon Carbide on Canvas). Unetched; 500 ×

very light pressure on the final wheel, but the relief effect is eliminated only by returning the specimen to the abrasive papers.

Etching: 5% aqueous hydrofluoric acid has been used to etch titanium. The authors found they could more easily control the action of the mixture of hydrofluoric acid, nitric acid and glycerol ("A-etch") and the mixture of hydrofluoric acid and glycerol ("B-etch") recommended in the paper referred to at the outset. Good results were also obtained with Keller's etch (1% HF, 1½% HCl, 2½% HNO_3, balance H_2O), which is often on hand in the laboratory, and with a simple modification in which the hydrochloric acid was omitted.

held at temperature for 1 hr., and quenched in cold water. Another series of specimens was cooled in air after similar heating cycles.

To determine the effect of time at temperature, specimens were treated at 1600° F. for 7, 29, and 75 hr., then water quenched.

87-Lb. Ingot, As Cast — Forged to 1½ In. — Forged, Hot Rolled to ⅝ In.

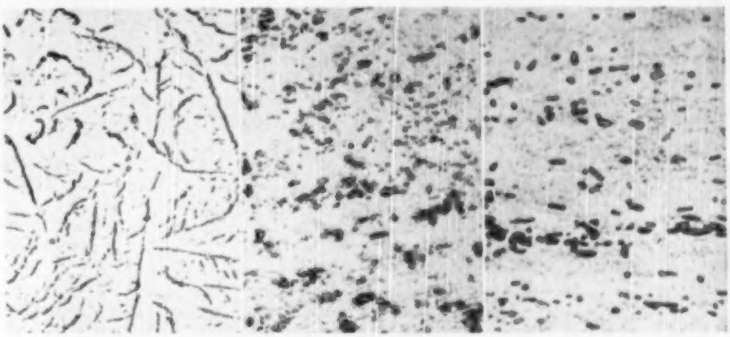
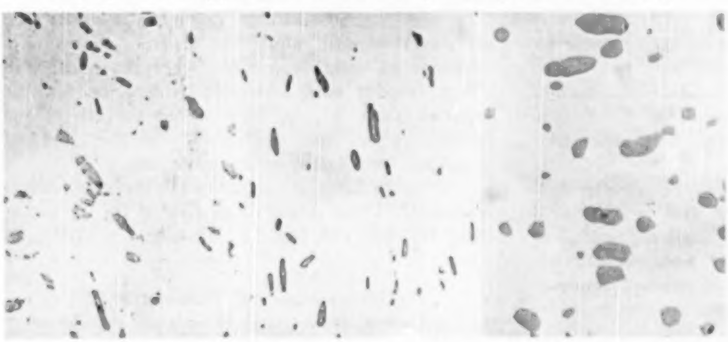


Fig. 2 — Commercial Titanium Containing 0.78% Carbon. Unetched; 100 ×

Fig. 3 — Carbide Distribution in Commercial Titanium (0.78% Carbon) After Heating for 1 Hr. and Water Quenching. Unetched; 500 ×



Quenched From 1300° F. — Quenched From 1600° F. — Quenched From 2100° F.

Heat Treatment

Specimens for heat treatment were obtained by cropping a piece from the large billet described in our article in the August issue of *Metal Progress* and separately forging down to a $\frac{5}{16}$-in. square rod. Pieces about $\frac{3}{16}$ in. long were cut off this rod and heat treated in an ordinary laboratory furnace. No effort was made to exclude gases except to pack the pieces in cast-iron chips. The furnace atmosphere was maintained slightly oxidizing. Specimens were heated to 1300, 1500, 1600, 1650, 1700, 1800, 1900, and 2100° F. (the last in a salt bath furnace),

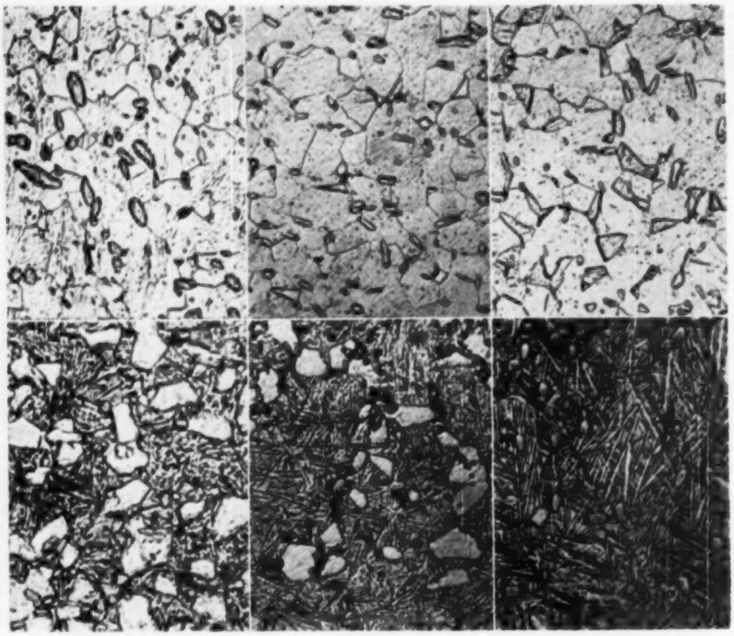
Structures

The microstructures of the ingot, forged slab and hot rolled plate are shown in Fig. 2. All show a matrix of alpha titanium. In the ingot the carbides are arranged in groupings resembling strings of beads. The forged material has a random distribution of spheroidal carbides. Some directionality is evident in the particles in the rolled metal.

None of the heat treatments had much effect on the amount of free carbide. It is evident that the solubility of carbon in titanium is very much less than 0.78% over a wide range of temperature, or else that titanium carbide dissolves extremely slowly. Figure 3, for example, shows the distribution of carbide after quenching from 1300, 1600, and 2100° F. The only change is in the growth of carbide particles, which is first noticeable at 1900° F. and becomes pronounced at 2100° F.

The beginnings of the alpha-to-beta transformation in the matrix material are observable in the specimen quenched from 1500° F.; small triangular patches of material exhibiting a marten-

1300° F. 1500° F. 1600° F.



1650° F. 1700° F. 1800° F.

Fig. 4 — Transformation in Commercial Titanium (0.78% Carbon) After Heating for 1 Hr. at Temperatures Shown and Water Quenching. Keller's etch; 500×

sitic pattern can be seen. These increase in number with temperature (Fig. 4), until they have completely replaced the untransformed alpha titanium in the specimen quenched from 1800° F. In the specimen quenched from 1300° F., only alpha titanium and carbide can be seen.

The analogy with martensite formation in steel is obvious. Unfortunately for the metallurgical engineer, the structural analogy does not extend to mechanical properties. Several tests were made and all indicated little promise of marked improvement of properties through quenching of material of this composition.

Microhardness Tests — Microhardness determinations with a Bergsman tester and a 25-g. load were made on a specimen quenched from 1700° F. The transformed material had a Vickers hardness of 294, and untransformed alpha titanium, in the same specimen, gave a reading of 326.

Diffraction Patterns — An annealed and a water quenched specimen were examined with a Seeman-Bohlin camera. Cobalt radiation at 30 kv. was used. Both specimens gave patterns characteristic of alpha titanium. The only difference was a slight broadening of the lines in the pattern obtained from the quenched specimen, apparently as a result of quenching stresses. There was no evidence of either retained beta titanium or of an intermediate transition phase. (This diffraction work was done by F. W. von Batchelder of the Naval Research Laboratory.)

Microstructure — The microstructure of a quenched specimen at 2000 diameters is shown in Fig. 5. The structure seems much less acicular than when viewed at lower magnification.

Tempering — An effort was made to determine whether the properties of the quenched material could be changed by reheating so as to produce tempering or aging effects.

To make the tempering tests, a $1\frac{1}{2} \times 2\frac{1}{2}$-in. block of the $\frac{5}{8}$-in. thick rolled plate was heated for $1\frac{1}{2}$ hr. at 1800° F. and quenched in cold water. It was then split along the central plane and a number of small specimens were machined out. That face of each specimen which was on the central plane ($\frac{5}{16}$ in. from either surface of the original plate) was used for the tests. Hardness readings were taken on all specimens.

One specimen was examined in the as-quenched condition. The others were heated for $\frac{1}{2}$ hr. at 300, 425, 550, 675, 800, 925, 1050, and 1175° F. and

Fig. 5 — Commercial Titanium (0.78% Carbon) Heated for 1 Hr. at 2100° F. and Water Quenched. Keller's etch; 2000×

As Quenched | 16 Hr. at 925° F. | 16 Hr. at 1050° F. | 16 Hr. at 1175° F.

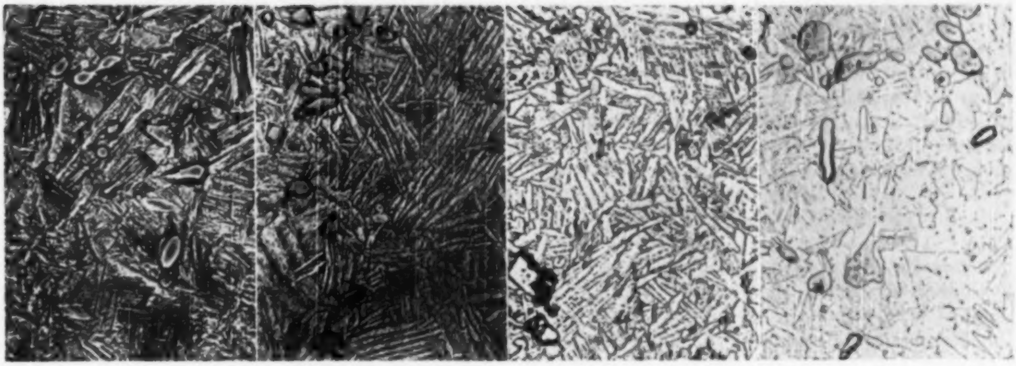


Fig. 6 — Effect of Tempering Commercial Titanium (0.78% Carbon) After Water Quenching From 1800° F. Remington "A" etch; 500 ×

water quenched. Hardness readings were taken. Heating was resumed at the same temperatures for an additional half hour, then an hour, and so on. At the end of the tests, hardness readings were available for material tempered over a wide range of temperatures and for times from ½ to 16 hr.

No change in microstructure was noted after treatment at 925° F. or below. After treatment at 1050° F. for 16 hr., the martensitic pattern became less pronounced. After treatment at 1175° F., it virtually disappeared, leaving a normal matrix of alpha titanium grains. These changes are shown in Fig. 6.

No changes occurred in the hardness of the specimens (measured as Rockwell G and as 10-kg. Vickers) after any of the tempering treatments.

It seems definite, therefore, that the transformation of beta titanium to the alpha form is not suppressed by quenching.

Effect of Time in Beta Range — Figure 7 shows the structures of specimens water quenched after 1, 7, 29 and 75 hr. at 1600° F. Longer holding time in the alpha-plus-beta range evidently results in a greater degree of transformation. This could be due either to inherent slowness of the alpha-to-beta transformation, or to the broadening of the alpha-to-beta temperature range as a result of pick-up of atmospheric gas.

To pursue this point, the third specimen of Fig. 7 was annealed, then reheated for 1 hr. at 1600° F. and water quenched. The resulting structure (last micrograph of Fig. 7) showed nearly as

7 Hr. | 29 Hr. | 72 Hr. | Annealed & Requenched

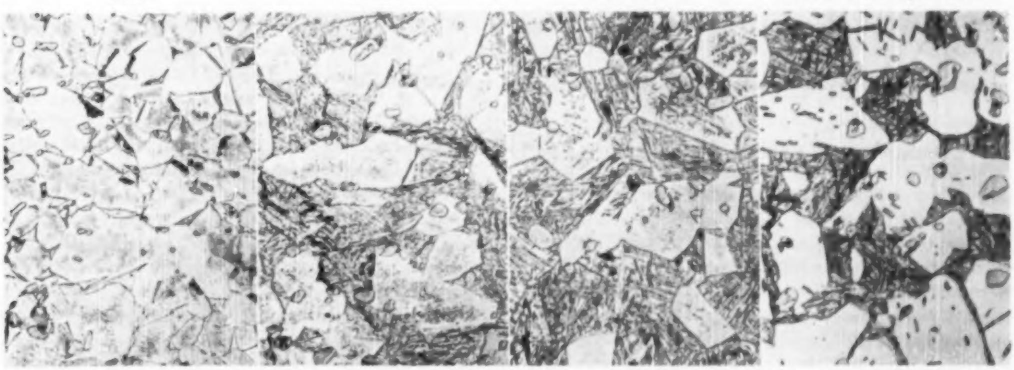


Fig. 7 — Effect of Holding Time at 1600° F. on As-Quenched Structure. Keller's etch; 500 ×. Structure at extreme right obtained by annealing the 72-hr. specimen at 1800° F., then requenching after 1 hr. at 1600° F.

great a degree of transformation as before the reheat treatment. Heating for 75 hr. had permanently altered the response to heat treatment, indicating that the transformation range had been broadened by pick-up of gas. The transformation range of titanium-carbon alloys therefore cannot be accurately determined by heating small specimens in air, for they soon become titanium-carbon-oxygen-nitrogen alloys.

Summary

The solubility of carbon in either alpha or beta titanium is very much less than 0.78% over a wide range of temperature.

The addition of carbon to titanium and the pick-up of atmospheric oxygen and nitrogen widen the temperature range of the alpha-beta transformation.

Beta titanium is not retained in appreciable quantity when commercial titanium is quenched, nor is a hard transition phase formed. The material is consequently not hardened by quenching. The microstructure of quenched titanium bears some resemblance to that of martensite.

The hardness of quenched titanium is not greatly affected by tempering No change in structure occurs except for a gradual fading of the martensitic pattern and emergence of a pattern of resolvable alpha titanium grains.

Correspondence

Notes on Russian Metallurgy

HEATHFIELD, SWANSEA, GREAT BRITAIN

Several interesting points have been raised by Mr. Brutcher in his article on "The Iron Curtain in Metallurgical Literature" (*Metal Progress*, September 1950, page 331) and I feel I can help Americans to understand the background of the curious and, at first sight, mysterious changes which the Russian technical literature has undergone during the past 15 years. My opinions are based primarily upon personal observations made between 1939 and 1947 in occupied Poland, the Ukraine, in and near Moscow, and finally back in present-day Poland.

Here is what I have to say, point by point:

1. The full reasons for the simultaneous "disappearance" of the four journals *Metallurg*, *Stal*, *Teoria I Praktika Metallurgii*, and *Uralskaya Metallurgia* were never explained, although this move was not inconsistent with the general centralistic tendencies of the Russian administration. Suspension of publication was not unexpected, because subscribers had been notified in advance. There were also items in the technical press informing potential readers that a new *Stal* was to appear in Moscow, starting in January 1941, as the official monthly publication of the People's Commissariat of Ferrous Metallurgy (abbreviated "Narkomtshermet") and would replace the four journals which appeared hitherto.

I believe that the demise of the four provincial journals, published in Leningrad, Kharkov, Dniepropetrovsk and Sverdlovsk, respectively, had been accelerated by the scandal which arose around the so-called Dobrokhotov furnaces, and for which two of these journals were considered to share the blame.

The scandal arose in the following way: A series of articles on furnace design appeared during the years 1937 to 1939 in *Stal* (Kharkov) and in *Teoria I Praktika Metallurgii* (Dniepropetrovsk) written by two professors of the Dniepropetrovsk Metallurgical Institute, Dobrokhotov and Kazantsev. They suggested that the orthodox design of open-hearth furnaces is wrong, and that efficiency and output could be greatly increased if the design were modified. The main innovation proposed was to build the hearth with a length-to-width ratio of unity (a square hearth) instead of the conventional rectangular shape with $l \div w = 2.5$ or so. The inventors of the new theory supported their deductions with many formulas which looked highly scientific and therefore convincing.

In view of the miraculous outputs promised, this new and "overwhelming" idea was immediately endorsed on the top level and proclaimed a major achievement of Soviet technical thought! I do not know whether pilot-plant experiments were undertaken, but I do know that the brand-new Azovstal works in Mariupol was equipped with several 450-ton Dobrokhotov furnaces.

What followed was probably one of the great-

est fiascoes in the history of metallurgical engineering. There was an inherent tendency for the roofs in the square furnaces to overheat. In order to keep the roof temperature within safe limits the working temperature had to be lowered. Consequently, the output was much below that of furnaces of comparable hearth area but of conventional design. Because of the rapid deterioration of the roofs these furnaces had to be shut down frequently — a source of continuous trouble and enormous expense. By 1940 the Dobrokhotov-Kazantsev theory had been officially condemned in an *ad hoc* country-wide discussion which was drummed up and published during the winter of 1940. It was, of course, more difficult to decide what to do with these monstrous furnaces than to organize the belated condemnation! Fortunately (or rather, unfortunately, from some points of view) the German invasion which followed soon after made this uneasy decision unnecessary; the Azovstal blast furnaces and steel melting shops were blown up in the autumn of 1941 by the retreating Russians.

2. The "miraculous" wire-drawing dies inferred by Mr. Brutcher on p. 374 of his article would deserve closer attention than is possible to devote to them here. Suffice it to say that the only sintered carbide material which was supposed to be equivalent to the foreigners' "Widia", "Böhlerit", or "Ramet" was manufactured in the U.S.S.R. under the name "Pobedit". It was absolutely the worst product of the kind I have ever seen, either as a cutting tool tip or as a drawing die. In one case the speed of a wire-drawing machine provided originally with Widia dies had to be considerably *reduced* when the prewar stock of original dies had been exhausted and Pobedit substituted.

3. The number of papers, articles, and books on metallurgical topics published in the U.S.S.R. is considerable — possibly equal to that in the United States. The quality of original work varies within wide limits, with a strong inclination toward involved mathematical formulations based upon meager and unilateral experimental evidence. Gubkin can be considered an example of this kind in the field of plastic working of metals — apparently he is one of the leading authorities in the U.S.S.R. on this subject.

The number of books published on technical subjects is very large, and many are quite comprehensive and long — 600 pages being an average. There are also numerous translations; for example, the well-known book by Camp and Francis on the "Making, Shaping, and Treating of Steel" was translated into Russian toward the end of the war, but is divided into three volumes. Their over-all cost is 120 rubles or £22 according to the official rate of exchange ($62.50), or about one fifth of the monthly salary of a medium-paid scientific worker in Russia.

A university professor gets 1000 to 1200 rubles monthly less income tax and less 10% to cover the nonstop internal loans, whereas a shabby suit of a quality which would make it unsalable in any other country costs about 500 rubles, a pair of plain shoes 200, and a pound of solid chocolate costs 45 rubles. These figures contain the explanation for the bulky size of Russian technical books, since the authors are paid by the number of pages they write! There is little sales expense because the customers are usually state-owned works and offices who subscribe in advance for all books on metallurgical, chemical, or any other specialty. For this reason many of the books listed in the official catalogs are often unobtainable, even in Russia.

N. H. Polakowski

Vanadium

Schenectady, N. Y.

The paper on production and properties of vanadium, by Dr. A. B. Kinzel in the September issue of *Metal Progress*, was particularly interesting to us since we have been doing work along the same lines. The Electro Metallurgical people should be congratulated on doing a difficult job expeditiously and in making large amounts of vanadium early in the development.

There are two matters in his reference to our work, which has now been published in the October issue of the *Journal of the Electrochemical Society*, p. 311. First, the impression might have been given in the oral presentation of our paper — which was all that was available to Dr. Kinzel at the time — that we prepared vanadium powder by calcium reduction of the trioxide and, secondly, that our yields were only about 53%. This impression persists in his reporting of our work. Our process (calcium reduction of V_2O_5) yields massive metal, and the yield is ordinarily about 75% on the 100-gram scale. In scaling up this process to several pounds, yields of the order of 90% would be anticipated.

We were a little surprised at the low elongation figures shown in the data sheet, as our metal has frequently shown elongations of several times 7%. Since publication of the article, Dr. Kinzel has advised us that he too has often obtained that value but preferred to quote the figure more readily achieved. It would seem that the oxygen content of the metal tested probably lay in the high

end of the range quoted, as the effect of oxygen on the ductility of vanadium is quite drastic. In our experience, metal with about 0.1% oxygen is unworkable at room temperature, although Dr. Kinzel's laboratories have produced metal with higher oxygen content and workable at room temperature by virtue of hot work orientation.

Alan U. Seybolt
Robert E. McKechnie
Knolls Atomic Power Laboratory
General Electric Co.

Oxygen for Steel Refining

Paris, France

It might be interesting to recount briefly investigations during the past three years by "IRSID" (the French cooperative Institute for Steel Research) on the use of enriched air in steel metallurgy and its prospects of future success.

It is known that German efforts in this direction date back to the 1930's, and enriched air has been blown to basic converters for as much as fifteen years at Maximilienshütte in Sulzbach, Bavaria. Belgian tests started in 1949 at Ougrée-Marihaye. In France, experiments by IRSID and the Senelle-Maubeuge Co. started in 1947.

The principal advantages concerning the use of air with 25 to 42% oxygen in basic (Thomas) converters, other than as an efficient means of correcting a cold blow, are:

1. Operations are speeded. A blow with 40% oxygen is completed in half the usual time. Generally speaking, present plants cannot handle the added capacity without extensive remodeling.

2. Much more scrap can be remelted. Since each cubic meter of hot nitrogen issuing from the converter takes enough heat to melt 1.4 kg. of scrap steel (that is, 1 lb. per 12 cu.ft. of nitrogen), air enriched to 30% oxygen (which seems the most convenient routine practice) can add 125 kg. per metric ton (250 lb. per net avoirdupois ton) of blast iron to the weight of the ingot cast, which is 19 metric tons (21 net avoirdupois tons) for the converters of the Senelle plant.

Economies depend upon the relative costs of molten pig iron, purchased scrap and oxygen, as well as the existing means and costs of re-treating in-plant scrap, as in the openhearth furnace. Of course, remelting in the converter is much more interesting for plants which, like Maximilienshütte, do not run openhearth furnaces, than it is for most European continental plants, which use basic converters for refining iron and remelt only low iron percentages with steel scrap in their openhearth furnaces.

3. Nitrogen in the resulting steel can be largely reduced, and, if the air can be enriched to 40% oxygen, which seems to be the highest limit practically serviceable, the steel will probably not retain more nitrogen than if refined in an openhearth furnace. Since nitrogen appears to be absorbed at mid-blow, during transition from the decarburization stage to the dephosphorization stage, perhaps it may be sufficient to use 40% oxygen for this brief time only.

Possibly a rotating drum-shaped furnace would be better for the use of pure oxygen than the conventional Thomas converter. This would be an alternative to the injection of pure oxygen in the bath of an openhearth furnace containing as much as 80% high-phosphorus (1.80%) molten iron and only 20% scrap. Work along the latter line was instituted in 1948 by IRSID at the Pompey steelworks. It was quickly proven that a charge can be dephosphorized almost completely during the time the original average 2.80% carbon was reduced to 1%. Contrary to the melter's expectation, it was found easier to dephosphorize than to get the decarburization under way.

In the same plant, the injection of oxygen in the oil burners of an openhearth furnace showed that injection of 875 cu.ft. of oxygen per net avoirdupois ton of steel increased the rate of production of the furnace by 25% and decreased the oil consumption from 270 to 224 lb. per ton.

While some increase in furnace maintenance and a small anticipated loss in furnace life would be taken care of, the latter could by no supposition amount to the increase in production rate, especially for an all-basic furnace chamber, which appears to be necessary in order to get the best results from high-intensity combustion of oil with oxygen and resulting hard driving of the plant.

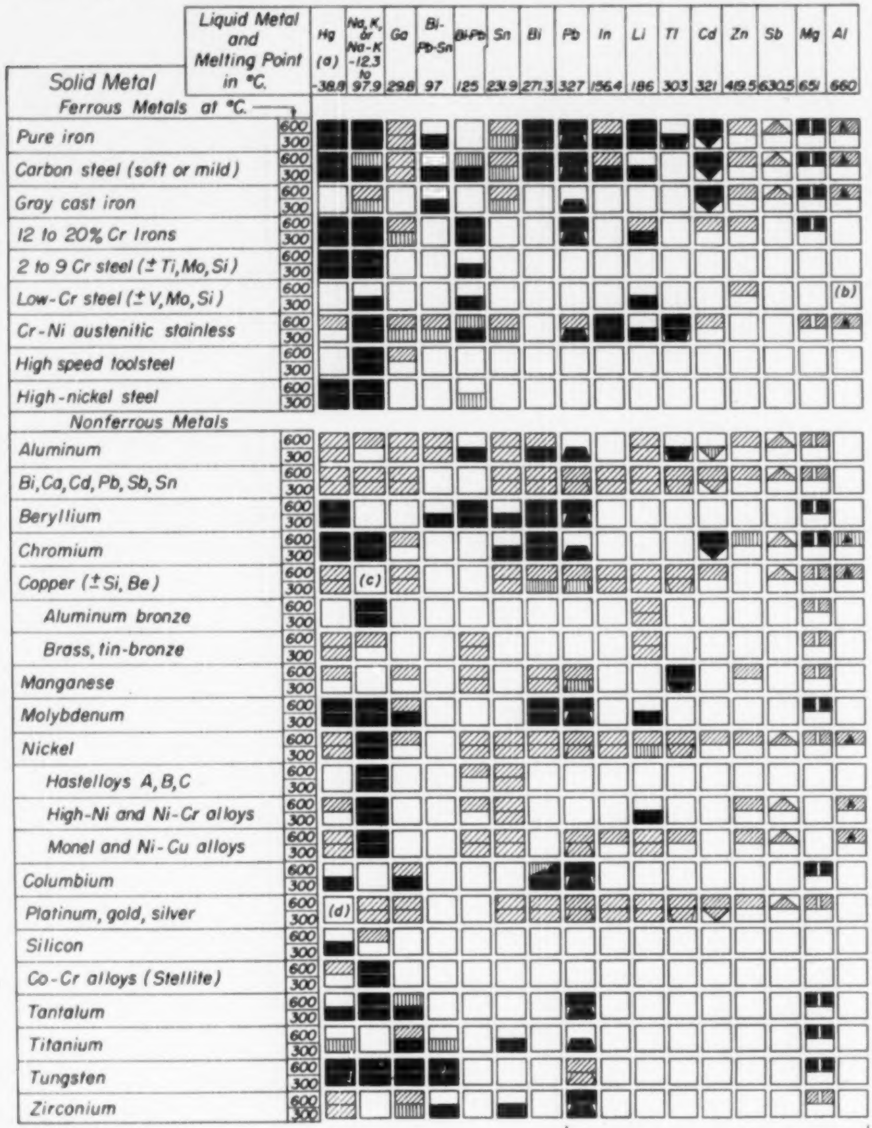
Indeed, it is the opinion of the present writer that when cheap oxygen (enriched air) is available, perhaps its proper usage will be in the refinement of a 100% molten iron charge in hearth furnaces or rotating furnaces especially designed for the process.

G. Husson
Head of Steelmaking Department, IRSID

Resistance to Attack by Liquid Metals

Compiled by LeRoy R. Kelman, Walter D. Wilkinson and Frank L. Yaggee

From "Liquid Metals Handbook", Office of Naval Research Publication NAVEXOS P-733



Degree of Resistance — Attack, mils/yr.

- Good ······ Considered for long-time use ····· <1.0
- Limited ····· For short-time use only ······· 1.0 to 10
- Poor ······· No structural possibilities ········ >10
- Unknown ··· No data for these temperatures —

Truncated or special shapes indicate that data are for melting point of liquid metal

(a) Data are for static systems; ferrous alloys attacked by moving Hg unless it contains an inhibitor (Ti or Mg)

(b) Vanadium steel, limited resistance at 660°C.

(c) Beryllium-copper, good at 300 and 600°C.

(d) Platinum, poor at 300 and 600°C.

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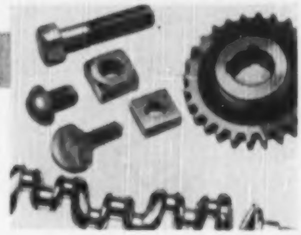

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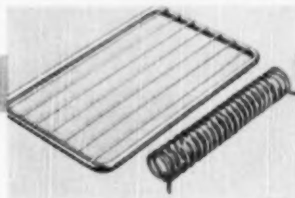

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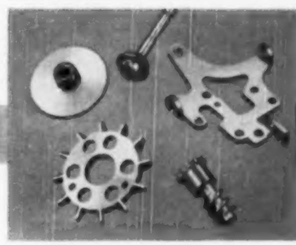

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Information gained from operation of plutonium piles and from the design of mobile power plants for military purposes indicates that fuel costs of an atomic power plant will be on the same order as fuel for conventional power plants, and that the higher first cost of atomic power plants must be amortized through utilization of byproducts.

Power From Atomic Reactors*

THERE are few subjects about which there has been so much talk and so little said as about atomic power. Interest in the subject seems to be high, and the emotional content of most presentations adds little to the clarification of the issues. I will try my best, therefore, to give you a report as to where we are now, will try to call your attention to trends which seem to me to be worth watching and, finally, to suggest the problems and issues which are emerging and will require attention at some future time.

We can classify most of our problems in two main categories, namely, technical, and economic. These I will discuss in turn.

Technical Problems — To date we have been almost exclusively preoccupied with problems in this category. You will recall that nuclear reactors are the machines for converting the energy available from the chain reaction set up by neutrons in purified uranium into useful forms (a slowed-down atom bomb explosion). The technical problems are many and have often been described:

1. Materials to stand higher temperatures than result from chemical reactions.
2. Materials which show minimum damage under the intense bombardment of neutrons and other particles in the interior of the reactor.
3. Materials which do not absorb and waste an excessive proportion of the available neutrons.
4. Shielding of personnel and instruments.
5. Control gear with response times adequate for safety.
6. Heat transfer rates higher by an order of magnitude than those conventionally used.
7. Control of radioactive materials produced in the fission process and deposited with the fuel elements to the detriment of the neutron economy.
8. Safe disposal of radioactive wastes.

It is with precisely these problems that our huge National Laboratories have been preoccupied since 1945. Much progress has been made but, as in other applied research programs, just how much is difficult to assess without some full-scale trials.

This brings us to the second major phase of the current reactor program, and that is the specific reactor projects. These are four in number:

1. **A materials testing reactor**, designed for the highest neutron flux yet attempted. Construction is well advanced.
2. **A land-based prototype of a submarine propulsion reactor** which is to operate with slow neutrons with which we have had extensive experience. Construction is well under way.
3. **An experimental breeder reactor** to discover whether more fissionable material can be produced than is consumed. This reactor will operate with fast neutrons. (We have one other reactor operating in this range.) Construction is practically complete; installation is beginning.
4. **A ship propulsion reactor** to operate in the intermediate neutron-energy range, in which we have had no experience. Now in advanced stages of engineering design.

Progress on these reactors gives us for the first

By Lawrence R. Hafstad
Director
Division of Reactor Development
U. S. Atomic Energy Commission

*Slightly condensed from "Reactor Program of the Atomic Energy Division", address before the American Petroleum Institute, Los Angeles, Nov. 15, 1950.

time, since 1942, an objective measure of the "state of the art" in reactor technology. In general, the program is progressing slightly better than I expected but not as well as I had hoped.

The important thing is that the delays were not due to unexpected technical troubles. Our worst bottleneck, for example, has been the production (in pure form and in ton quantities for structural purposes) of a chemical element which, until a year ago, was essentially one of the curiosities lumped under the rare earths in the periodic table. To a technical man, a bottleneck of this kind isn't even interesting; it's only a damned nuisance. Other delays have been due to procurement difficulties in the case of essentially conventional items such as tanks, valves and pumps. I fear that it is almost an occupational disease on the part of a scientist to focus attention on the part of a problem of particular interest to him and neglect what appears to him to be prosaic.

In summary then, so far as specific reactor projects are concerned, our laboratories seem to have done an adequate job of applied research, and to have provided our designers with adequate handbook type of data. Our designers in turn seem to have successfully avoided gross troubles which might be uncovered early in a construction program. For a final and more detailed answer, we must wait until the present generation of reactors has been carried through the de-bugging stage and is in actual operation.

So far we have been discussing technical problems in the current crop, the present generation of reactors. It is not too surprising that there should be considerable discussion as to what types the next generation of reactors should include. Remember, reactors are expensive. Small ones cost from $1 million to $5 million; full-grown ones $25 million to $50 million. Reactor designs are numerous. What with breeders and nonbreeders; high, low and intermediate neutron energy; high, low and medium temperatures; natural, slightly enriched and highly enriched fuels; homogeneous and heterogeneous fuel distributions; assorted moderators, coolants and corrosion resisting coatings, the number of permutations and combinations runs high. The problem is not to invent a reactor. The problem is to select one which will yield maximum returns.

What, really and honestly, are the *needs?*

First, let us clear the air of some unnecessary confusion. Various articles state or imply that there is a great and immediate possibility of use for civilian atomic power which is being sabotaged by *(a)* the military, and *(b)* the private power interests. A Russian physicist, writing in the Moscow *Literary Gazette*, recently quoted in the *Daily Worker*, for example, claims that Americans "sabotage the peaceful use of atomic energy because it would outdate old machines and make coal and oil valueless". If such statements contain even one iota of truth, then in my present position as Director of Reactor Development, I would expect to be a focal point for such pressures, but I can only report that in nearly two years they have failed to develop either from above or below!

In the meantime, let us return to our technical problem, namely, that of picking, in the national interest, the most promising reactor or groups of reactors. First and foremost, we *need* production reactors for producing fissionable material for either military or civilian use. Next, we can probably *use to advantage* mobile power reactors if the cost in both dollars and fissionable material does not prove to be prohibitive. Finally, we can *justify* heavy commitments to reactors producing electric power only if and when the cost of this power bears a reasonable relationship to the cost under comparable conditions of power available from conventional fuels.

These are the boundary conditions on our problem.

Now, which reactors should be built? To justify building an expensive reactor, we must, or should, have a *demonstrable need.* To assess the need we must know costs, but costs can be determined only by first building reactors! To break out of this vicious circle we have used the fact that, for the military needs, the unknown economic factor is less compelling.

We can draw a few other general conclusions from our reactor experience to date: For example, with fissionable material in great demand for bombs, we must concentrate on power reactors which, at least partially, replenish the fissionable material used up. Mobile military reactors therefore converge on production reactors, and both should eventually be combined with breeding of new fuel. This leads us to the breeder reactor, which continues to be highly desirable. Furthermore, the civilian power reactors, precisely because of their need for the lowest possible cost of power produced, are tending to interlock with production processes and therefore production reactors for military uses. Thus, instead of being separable into neat little problems which can be solved, one at a time by themselves, the trend appears to be toward greater complexity with a pronounced interlock between production of fissionable material and the construction of mobile reactors for the military, and reactors for civilian power.

Note how insistently the economic factor intrudes itself into what we would like to consider as a purely technical problem. Let us therefore turn to

the economic problem before trying to summarize the desiderata for the next generation of reactors.

Economic Problems — Critics usually make the assumption that civilian atomic power could be made practical (that is, cheap) and generally available if only those in authority had the will to do it. The assumption is that by another billion-dollar crash program, Manhattan District type of attack, the remaining necessary "secrets" could be uncovered and the real atomic era ushered in. Actually, there seems to be little in common between atom bomb and civilian power except the language. They differ in kind rather than in degree. The atom bomb was almost uniquely a black-or-white problem; it was either a grand success or a colossal failure.

The civilian power problem is quite different. Enough technical facts have long been known to assure us that electric power can be produced if we are willing to pay the price. It is for this reason that the crash program is the last thing we want. If correct bookkeeping procedures were followed, the high costs of such a program would have to be charged to the power ultimately produced, thus *raising* rather than lowering its cost.

In many respects, economic factors make the power problem a tougher one than the bomb problem and we will have to look elsewhere for an analogy. Perhaps the closest we can come is the problem of private flying for the airplane industry. Here the technical problems are already solved — at least to a first approximation, but until it becomes much, much cheaper, willing potential customers will continue to look upon private planes as an unjustifiable luxury. Similarly, at the moment, civilian atomic power is potentially available, but only as a luxury civilians can't afford.

Lawrence R. Hafstad

LONG a student of radio waves, DR. HAFSTAD became director in 1940 of the work which led to the proximity fuse. Previously with RICHARD ROBERTS and MERLE TUVE, he had verified the German report that the uranium atom could be split. Since 1948 he has directed the development of nuclear reactors for the U. S. Atomic Energy Commission.

Single and Multiple-Purpose Reactors

Figures in the literature on estimated costs for atomic energy vary by at least a factor of ten. I am not going to give you more accurate cost figures for three very good reasons:

1. They do not exist within the Atomic Energy Commission.
2. If they existed, they could not be released for security reasons.
3. If they did exist and if they could be released, I wouldn't believe them anyway.

My pessimism in this matter stems from the fact that two variables are involved, both of which are uncertain. As in other human activities, we must consider both the first cost and the upkeep. The first cost is still unknown for we have never even designed, much less built and operated, a reactor intended to deliver significant amounts of power economically. The second factor (upkeep) is even more uncertain since all fissionable material to date has been produced in a government monopoly on a crash program basis in such a way that precise cost allocation to any one item simply cannot be made.

The only really significant figure for the cost of civilian power from atomic energy would be one based on a power system which pays its own way with civilian (instead of military) uses of byproducts — all the way from the uranium mines to the disposal dump.

Even excepting the additional complications introduced by the security problem, cost estimates are quite unsatisfactory, both inside the Commission and in the open literature. Estimates invariably turn out to be too low. It is for this reason that my own approach has been to set upper limits on cost based on the firmest available costs on the most nearly similar reactor either built or under construction. We cannot take seriously those estimates based on the cost of low-temperature reactors used for the production of plutonium and the assumption that they can be redesigned for higher temperature operation. If this were easy to do it would have been done in the first place and, if it is not easy to do it is likely to be expensive. Thus, I have been driven back to the ship propulsion reactor as our currently best available yardstick for nuclear power costs. A rough figure for this has been given as $1400 per kw-hr. installed capacity for nuclear power. Compare this with $133 for the corresponding equipment of a conventional power plant!

Now we know that while, in a mature and

highly competitive business such as the power industry, it will be slow work to reduce further the $133, there are many savings which can be made in the $1400 figure. Let me list some of the high-cost items where savings seem possible.

1. High development costs of a prototype reactor.
2. High costs for meeting naval requirements of weight and space.
3. High cost of reprocessing fuels.
4. Lack of volume production.
5. Extreme security precautions.
6. Extreme precautions for personnel safety in cramped quarters.

If — with savings in these items, and the almost certain technical improvement in a field as new as atomic energy — we can pick up a factor of two or three, we could begin to close in on the competitive figure of $133 for corresponding capital costs of the conventional installation.

To effect these savings, fastest progress would be made if we could move toward the design and construction of reactors on a competitive bid, fixed-price basis, or by otherwise utilizing a profit-making incentive. This will not be easy but I believe that it can be done if we in Washington have both the will and the ingenuity.

Turning to the fuel cost, we can only emphasize that even for nuclear fuels this item is not negligible. Taking from the open literature the figure of $20 per gram for nuclear fuel, we still get a cost of one mill per kw-hr., as compared to 2 mills for conventional fuels. The $20 figure is almost certainly low and seems likely to increase as the supply of high-grade uranium ore runs out. For single-purpose civilian power-producing reactors burning U-235, the conclusion is that the cost of fuel will be about the same as for conventional plants, while the cost of the installation (and probably its operation) will be considerably higher. Exactly what the costs will be cannot be known until we can try the experiment.

Multiple-Purpose Reactors — So far I have talked mostly about reactors whose sole reason for existence is the production of power. But we have reactors producing plutonium which throw away their heat. Suppose this heat could be put to some use — even the distillation of sea water — what then is the economic picture?

One thing is certain — utilization of byproducts can sometimes salvage an otherwise uneconomical proposition. Technically, a reactor to produce both power and plutonium is not out of the realm of possibilities. We don't know much about such a reactor yet. But if we can make one work, the value of the plutonium would allow us to charge off much of the operating cost to the production of the plutonium.

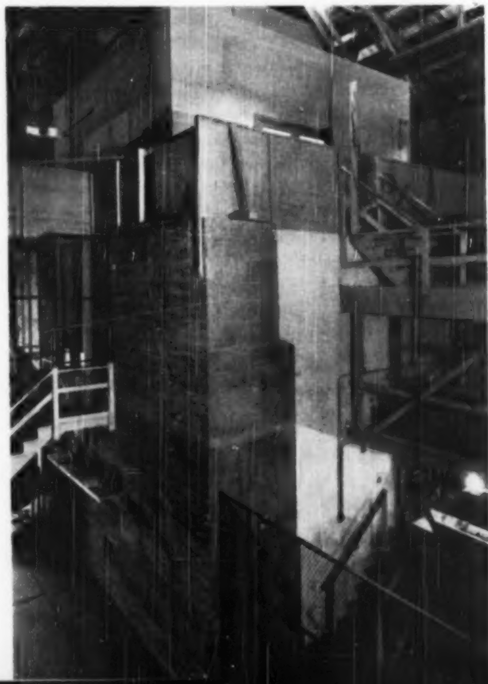
Industrial Participation

We can now see more clearly the nature of the joint government-industry effort to realize the potential in atomic energy. In some respects, it is clear only in terms of problems to be solved. But those problems have been identified sufficiently for both the Atomic Energy Commission and American industry to determine the most effective role each must play.

The level has been substantially raised in our reservoir of technical knowledge. We have more tools with which to work, but our work-load has increased even more. In the meantime, industry begins to see its own role not only in terms of job contracts, but in the promise held by the multiple-purpose reactor.

Suppose now that either out of the national laboratories or from industrial contractors we get a design of a reactor producing plutonium and which yields electric power as a byproduct. Does this finally usher in the atomic era? I'm afraid not. The major charges will still be carried by the military need for plutonium. Only if and when we can produce fissionable material which when used for civilian power will pay for its own pro-

Original Uranium Reactor (in Which a Chain Reaction Was Produced on Dec. 2, 1942) Re-Erected at Argonne National Laboratory. A 5-ft. concrete wall encloses a 21-ft. cube of pure graphite in which 52 tons of uranium metal and oxide is distributed. Control rods are on galleries at right; scientific observational equipment is housed in small building on top



duction costs can we truly say that the civilian atomic power problem has been solved. In the meantime we would be less than prudent if we did not take advantage of every opportunity to reduce over-all costs by an increasing emphasis on the use of byproducts, as in the past has been done so successfully by industry.

Assuming, then, that it is desirable to have greater industrial participation, and by this let us agree to mean responsible, cost-reducing, competitive participation, what problems will arise?

First and foremost there will be the problem of shortage of personnel. A recent search turned up a total of only 350 names in the whole country of people who list themselves either as mathematical physicists or as nuclear physicists. Of these, most will be engaged in university teaching, others will be suspect "intellectual pinks", so it is not surprising that we count our experienced reactor designers almost on our fingers. Essentially all are already committed and overcommitted by our present program, and nothing would cause more disruption in this program than an irresponsible uncontrolled proselyting of key personnel. This is a primary problem. Its solution will almost certainly lie in an expanded training program for our embryonic industry.

A second very serious problem will be that of unpredictable costs which may be introduced at any time during operation by government decree. These will be mainly in the fields of security, accountability for the fissionable material, and personnel safety both in and near the plant. Initial agreements can probably be worked out, but abrupt and arbitrary changes in the rules of the game after the play is underway are going to raise interesting questions.

A third category of problems which can readily be foreseen is that toward which the industrial "market survey" is aimed. In other words, what is the future market for the product? As is well known, the government is reluctant to commit itself for expenditures in future years. Yet in a development as ponderous as that of atomic energy, any privately financed industrial approach would have to be based on firm plans for five, ten or more years in the future.

Another knotty problem is that of the fair and equitable distribution among many interested groups of the opportunity to play an active part in this field. Finally, there is a category of legal problems, and possibly additional complications due to an international inspection system by the United Nations.

It is clear that problems are many and, viewed philosophically, it might well be said that we are currently engaged in trying to develop an atomic energy industry with none of the advantages of either our own or the Russian economic system!

Nearby Developments

Now let us return to the intriguing problem of picking the leading candidates for the next generation of reactors. There is now an expressed demand for reactors for the following purposes:

1. As a research tool, both by universities and by industry.
2. For mobile power, almost exclusively military.
3. For the production of fissionable material.
4. For the generation of power.

The first of these presents few problems since they can be small, safe, and relatively inexpensive.

The second, third and fourth are already large, complex and expensive and promise to remain so. Their development problems are inexorably interlocked. In order that these enterprises can be designed with lesser risk, we have established still another category of reactors, the experimental "test-prototype" reactors.

These are reactors which will permit us to separate the variables inherent in the large multipurpose reactors. The "experimental breeder reactor", for example, is one of these. It will enable the breeding problem to be studied essentially by itself with a minimum of interference from the demands of, let us say, high temperature, efficient production, or maximum power. A similar reactor which will permit us to test our knowledge, predictions, and techniques in connection with the homogeneous reactor approach has been authorized. Still another experimental reactor designed for the highest temperatures which could conceivably be obtained with "soon to become available" materials is on the drawing boards.

Summarizing, and focusing our attention on trends, we note that discussion and interest have shifted from the question of whether power reactors *can* be built, to which *should* be built and which will prove most economical. This represents real technical progress. Current efforts are proceeding on two fronts, a direct attack on those problems confronting production and mobile reactors, for which there is a present real demand, and a parallel attack on the applied research front, looking toward proved technological advances which at some future date can be safely incorporated in the main line of large reactors. We note a trend toward complex multi-purpose reactors with civilian power probably emerging first as a byproduct from production reactors and perhaps ultimately in its own right. Finally, we note an increasing interest in the Commission to consider proposals for industrial participation.

Excavations on the Site of Hammersmith. Blast furnace crucible in right foreground, foundation timbers for bellows in bottom center, pig bed at lower level (left center). The ridge extending down the river bank is the slag dump. Photograph by Richard Merrill

Twenty years after the Indians massacred the workmen and destroyed the new furnace at Falling Creek, Va., a blast furnace was built near Boston and operated successfully for over 20 years. It is now being excavated and later will be reconstructed.

Hammersmith — America's First Successful Iron Works

IN THE quiet little town of Saugus, Mass., is the site of a former industry of significance. It is from this spot a few miles from the coast line and perhaps 10 or 12 miles northward from Boston that the iron and steel industry traces its origin. It is here, a little over 300 years ago, that iron blast furnace operation started in this country and was successfully carried on for a number of years; here was the first successful iron works; here was the very birthplace of our iron and steel industry.

Many are familiar with this fact and much has been written of it in the past. It is thus not necessary, in that which follows, to dwell at length on many of the historic details, rather to make brief note of an earlier attempt at iron making in the new world. The unfortunate circumstances of this other venture give the Saugus works undisputed title as the *first* successful iron works; at the same time it may show how narrow was the margin by which it succeeded.

The discovery of iron ore in Virginia led to the building of a blast furnace at Falling Creek, Va. Before this plant could be put into operation, however, Indians killed nearly all of the workmen and inhabitants and destroyed the plant. For 20 years, up to the Saugus venture (and an almost simultaneous but less successful undertaking of the same company at Braintree) no further attempts at iron making in the Colonies are recorded.

The establishment at Saugus was called Hammersmith, after a district near London whence came many of its skilled workmen. According to record, the men and some materials arrived in this country in the fall of 1643, and this is the year which is usually quoted as the active beginning of the enterprise. From this date until some time between 1660 and 1680 the plant produced iron nearly continuously.

Although the furnace production was undoubtedly erratic, records indicate that in the summer of 1648 the rate was on the order of six to seven tons weekly. Not only was the iron cast in many useful articles, such as kettles and utensils, but a finery was also operated. Here the pig iron was reduced in carbon to wrought iron and then forged to bars. There is reason to believe that a rolling and slitting mill may also have been set up for making nails or bars used by the blacksmith.

Aside from the accounts of court proceedings, letters and business documents connected with Hammersmith and its principals, two outstanding monuments at the site have bridged the 300-year chasm of time to offer testimony in our present day. These are the so-called Iron Works House and the nearby mounds of slag.

The original company backing the colonial project agreed to provide housing for the general manager of Hammersmith. Today, authorities are in accord that the present Iron Works House is the result of such an agreement — a reconstruction which stands on the original foundations.

By E. L. Bartholomew, Jr.
Assoc. Prof. of Mechanical Engineering
University of Connecticut, Storrs, Conn.

The slag dump, although necessarily lacking the popular interest of the Iron Works House, is none the less significant. Despite the fact that much of it is known to have been later removed for roads or fill, it is still large enough to indicate the extent of the workings.

Undoubtedly these two markers of the past have kept the story of the old iron works alive. Thousands have visited and inspected the house and always among them the steelman or the metallurgist would invariably wander down to poke about in the old slag pile. In some of these visitors a determination was fired that someday this historic undertaking could be properly commemorated. This is the substance of today's story.

In the fall of 1943, just 300 years after the arrival of the workers from England, The First Iron Works Association was incorporated. Although set up to administer the Iron Works House, the Association grew rapidly to include members equally interested in the Iron Works itself. Gradually the words "restoration" and "shrine of the iron and steel industry" began to usurp the discussions at annual meetings. All of this culminated with the assurances of the American Iron and Steel Institute that, if a restoration program were to be drawn up, adequate assistance for its execution would be provided. This was in the spring of 1948. In the fall of the same year, excavation was in progress under the guidance of a competent archaeologist. As the plans were worked into shape and became more thoroughly organized, a program of careful research into the history of the Iron Works was begun, to supplement the exploration on the site. "Digging" and "discovery" have been the bywords through the past year.

Almost at the beginning, the foundations and part of the walls of the old furnace were discovered. In uncovering these the outline of the furnace and its crucible was revealed. Later some massive timbers which undoubtedly carried the bellows for blowing the furnace were uncovered. One of these beams measures 14 x 12 in. and most of it is amazingly sound. A length of conical pipe was located near the tuyere opening and is thought to be the nozzle connecting with the bellows.

On a gentle slope leading away from what must have been the hearth arch of the blast furnace the pig beds have been located. Some sand found in this region is foreign to the immediate locale and appears more like beach sand which could have been so used. One rectangular piece of iron, found in this area, measured approximately 15 x 11 x 3½ in. Chemical analysis of some iron, presumably a piece of a kettle cast from the furnace, shows it to be not greatly different in composition from modern cast iron used for similar purposes — not surprising, for the fundamental aspects of blast furnace practice have not changed.

From careful study of these findings, together with data gathered from the program of research into other early iron blast furnaces, it is reasonable to expect that an authentic restoration of the old furnace may readily be accomplished. This reconstruction will be delayed until all available information will have been searched and accurately evaluated. The furnace itself, the wheel, bellows, charging trestle, casting shed and other equipment attendant to furnace operation will be rebuilt.

Excavation has already disclosed the tail race from the water wheel which powered the bellows; some of its original planking is still in place. A short distance from the furnace along the race another foundation has been discovered, supposedly of the finery.

During the course of much tedious digging and sifting of earth, many small items have been discovered which have an interesting bearing on the former operations. Among these are bits of castings, wrought iron bars, and nails. Even small pieces of leather which may well have been part of the bellows were recovered from the environs of the bellows housing. Some of the loose stone from the vicinity of the furnace foundations has been exposed to high temperatures; one side is glass-like and of greenish hue. In view of the plant's nearness to coastal waters it has reasonably been supposed that shells were used as a flux. It is also a matter of record that later blast furnaces in this vicinity made almost exclusive use of sea shells for this purpose. To date, however, only meager evidence on this point has been exposed by the excavations at the established old working levels. A few bits of coral, authoritatively identified as such, and stray pieces of limestone have been found. The latter items complement some data in the business records which suggest that there had been some importation of fluxing materials. The precise nature of these materials, questions concerning their point of origin and the amount brought in to Saugus are matters which it is hoped will be clarified by further research.

At the present time, exploration continues on the site, there being much of the area as yet not thoroughly investigated. Similarly, records and documents pertaining to both Saugus and contemporary English iron works are being carefully examined. Restoration and a general rebuilding of the entire plant and facilities will follow the slow but sure completion of this work. Just when the last stone will be replaced, the last wooden peg driven home, no one can say now. When this day comes, there will once again have arisen the first successful iron works in America!

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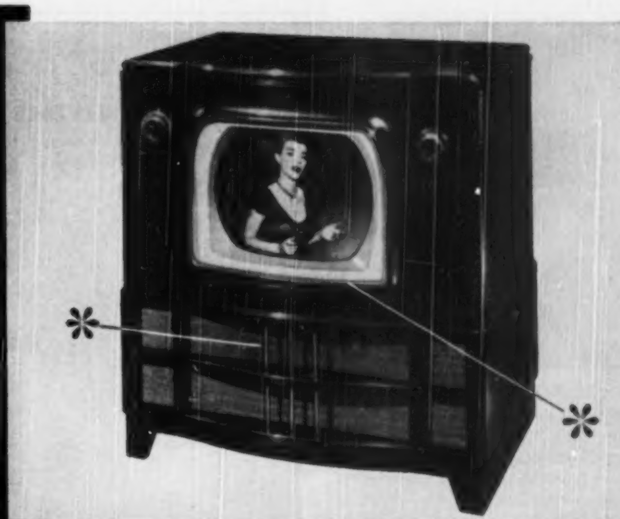

The newest Crosley Television Cabinets are striking examples of how copper and brass can be used to give products sales appeal as well as serve a utilitarian purpose.

All models, two of which are shown above, are equipped with gleaming bezels which frame the television screens. They are made for the Crosley Corporation from Revere 90-10 Commercial Bronze. The table model shown is equipped with two control escutcheons drawn from this same metal by the Rex Engineering Company, Cincinnati, Ohio. The table model also has two strips of .0016" Revere Soft Copper of 5½" width on the under side of the top of the cabinet. This acts as an insulator by conducting any heat generated, away from the wooden cabinets. For, although copper is the best heat conductor of the commercial metals, when highly polished it dissipates rather than absorbs heat.

Note on the console model, shown above, how the three Revere Brass Tubes add a touch of luxury and richness to the cabinet.

Perhaps Revere Copper or Brass or one of its other metals or alloys can help in the development and improvement of your product. Why not call the nearest Revere Sales Office and see?

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Personal Mention

Harry K. Ihrig

Announcement has been made by Allis-Chalmers Mfg. Co., Milwaukee, of the appointment of **H. K. Ihrig** as vice-president in charge of research. Dr. Ihrig terminates 17 years with Globe Steel Tubes Co., where he was vice-president and director of laboratories, to accept this new position. Dr. Ihrig has received awards from the University of Wisconsin (1949) and the American Institute of Mining and Metallurgical Engineers (Robert W. Hunt Medal, 1947). He holds 19 patents and is best known for his process of Ihrigizing, which provides for silicon impregnation of iron and steel to obtain a case which is very resistant to corrosion, heat and wear. Dr. Ihrig is a native of Wisconsin and obtained his bachelor's and master's degrees from the University of North Dakota and his Ph.D. from the University of California.

Morse Chain Co., a division of Borg-Warner Corp., announces that **E. W. Deck**, formerly manager of the Ithaca, N. Y., plant, has been named vice-president in charge of manufacturing.

Aurora Metal Co., Aurora, Ill., announces the appointment of **J. W. Lauder** as a metallurgist.

The Carboloy Co., Detroit, announces that **I. L. Wallace**, formerly superintendent of the carbide metal division, has been named manager of engineering on carbide and other special metals.

Frederick P. Hesch, formerly with Kaiser Aluminum Research Laboratory, has accepted a position in process engineering with Northrop Aircraft Corp., Hawthorne, Calif.

Taylor Lyman has been promoted by the American Society for Metals from associate editor of *Metal Progress* to publisher of the magazine. Dr. Lyman was editor of the 1948 edition of the "Metals Handbook".

E. C. Jeter

E. Claude Jeter, formerly plant manager of the Dearborn Iron Foundry, has been named plant manager of the Ford Motor Co.'s new foundry in Cleveland. Mr. Jeter has been with Ford since he graduated from Clemson College in 1928, starting in the analytical laboratory of the metallurgical control department. Soon afterward, he began his experimental work on casting processes and techniques. In 1944, he was placed in charge of foundry control under the chemical and metallurgical department and in the succeeding years rose to assistant superintendent, superintendent, and plant manager of the Rouge Production Foundry. Mr. Jeter is the author of many articles on foundry processes and techniques in the publications of the S.A.E., A.S.M. and A.F.S.

Robert S. Burpo, Jr., who has been recalled to active duty by the U. S. Navy, has been assigned to the material laboratory, New York Naval Shipyard, Brooklyn, N. Y.

John F. Carlson, who graduated from the University of Michigan in August, is now employed by Allegheny Ludlum Steel Corp., Brackenridge, Pa.

Bruce Carpenter, formerly superintendent of the openhearth and bessemer department of Algoma Steel Corp., Ltd., is now superintendent of openhearths at Youngstown Sheet & Tube Co., Youngstown, Ohio.

L. Paul Clare, who graduated from Lehigh University in June, is now an observer with Republic Steel Corp., Buffalo, N. Y.

Samuel L. Hoyt

The University of Minnesota, in its recent centennial celebration, conferred its Outstanding Achievement Medal on **Samuel L. Hoyt**, a graduate of Minnesota School of Mines and (after doctorate study at Columbia and in Germany) organizer of its department of metallography (1913). From 1919 to 1931 he was metallurgical engineer for General Electric Co., where he studied and perfected an idea gained from G.E.'s German affiliate, the Osram Co., wherein particles of excessively hard tungsten carbide, sintered and bound together with cobalt, are made into that most excellent cutting material known as Carboloy. Sam Hoyt's first technical publication described this epoch-making development in cutting tools before the tenth annual convention in 1928 of the (then known as the American Society for Steel Treating), and it is this work which was dwelt upon in the Minnesota award. From 1931 to 1939 Hoyt served as director of metallurgical research for A. O. Smith Corp., and since 1939 he has been technical advisor to Battelle Memorial Institute.

A. M. Aksoy has been appointed associate professor of metallurgy at Drexel Institute of Technology, Philadelphia.

After returning from eight months in Korea as a metallurgical consultant to the industry and mining division of the Economic Cooperation Administration, **Wayne L. Cockrell** is now employed in administration and liaison with Atomic Energy Commission contractors on metallurgical matters associated with reactor development.

Personals

Edward A. Livingstone, vice-president in charge of sales of Babcock & Wilcox Tube Co., Beaver Falls, Pa., has been named to the Steel Products Industry Advisory Committee.

Carl O. Lundberg, formerly with the Norton Co. research laboratories, is now a sales engineer in the Detroit office of Vanadium Alloys Steel Co.

R. C. Dartnell, Jr., who obtained his master's degree from West Virginia University in July, is now in the production department of the American Cyanamid Co., Calco Chemical Div., Willow Island, W. Va.

George A. Exley, formerly with the Bendix Radio Div. of Bendix Aviation Corp., has accepted a position with Hughes Aircraft Co., Culver City, Calif., as superintendent of guided missile production.

George L. Flint has been appointed metallurgist at the Richland, Wash., plant of General Electric Co.

Charles W. Andrews, formerly project engineer in the development laboratory, Brush Beryllium Co., has accepted a position of metallurgist in the jet division of the Tapco plant of Thompson Products, Inc., Cleveland.

Joseph A. Creevy, formerly field representative for the Youngstown Sheet & Tube Co., is now manager of pipe sales for the Newport Steel Corp., Newport, Ky.

Herbert D. Cronin, who graduated from the Colorado School of Mines in May, is presently employed as a metallurgical engineer by Harrington & Richardson Arms Co., Worcester, Mass.

Sherman S. Cross has been promoted from chief engineer to manager of operations of Brainard Steel Co., Warren, Ohio.

Robert R. Jones, formerly a research engineer with Thompson Products, Inc., Cleveland, has been appointed instructor in metallurgy at Lafayette College.

Wayland S. Bailey has accepted a position as associate professor of mechanical engineering at Norwich University, Northfield, Vt.

Philip C. Barr, who joined Allegheny Ludlum Steel Corp.'s training program in July, has been transferred to the titanium research division in Watervliet, N. Y., as assistant research metallurgist.

Harry Majors, Jr., formerly executive officer of the materials division at the department of mechanical engineering at Massachusetts Institute of Technology, is now director of the engineering experiment station at the University of Alabama, University, Ala.

Tak Matsuda, who received his M.S. from Case Institute of Technology in January 1950, is now enrolled at Stanford University working part time as a laboratory assistant in the department of metallurgy and studying toward his Ph.D.

George W. Metger, Jr., is now in the training program of the engineering department of Bendix-Westinghouse Automotive Air Brake Co., Elyria, Ohio.

Paul H. Morehead has been appointed detail engineer in the experimental division of the Buick Motor Co., Flint, Mich.

William E. Pearson, who received his M.S. in metallurgical engineering from Michigan State College in September, is now employed as a metallurgist with the Detroit Transmission Div., General Motors Corp.

Personals

C. C. Wissmann, formerly research metallurgist at Solar Aircraft Co., is now metallurgist for Los Angeles Steel Casting Co., Los Angeles, Calif.

Richard W. Wilson, formerly associate metallurgist at Armour Research Foundation, has joined the American Hoist & Derrick Co., St. Paul, Minn., as chief metallurgist.

Arnold S. Rose, formerly of the RCA Victor Div., has joined the special products division of the ITE Circuit Breaker Co., Philadelphia, as head of its research and development laboratory.

Alvin Shames, who recently received his master's degree from Pennsylvania State College, is now a research engineer at Battelle Memorial Institute, Columbus, Ohio.

L. R. Wolff, who graduated from Colorado School of Mines in May, is now a metallurgical assistant for Kaiser Steel Corp., Fontana, Calif.

Walter L. Finlay has been appointed research manager of Rem-Cru Titanium, Inc., Bridgeport, Conn., a manufacturing company jointly owned by Remington Arms Co., Inc., and Crucible Steel Co. of America. Dr. Finlay has been active in titanium research at Remington Arms Co. since 1947.

Seymour J. Sindeband, formerly technical director of American Electro Metal Corp., has been elected executive vice-president of Mercast Corp., New York City.

Oliver Smalley, president of the Meehanite Metal Corp., New Rochelle, N. Y., has been awarded the Gold Medal of the Gray Iron Founders' Society of America for his contributions to the industry.

Heppenstall Co. announces the appointment of **Raymond T. Porter** as eastern sales manager. Mr. Porter has been with the company since 1918 and has recently been sales manager in Bridgeport, Conn.

Donald F. Clifton, formerly a metallurgist at the Institute for the Study of Metals, University of Chicago, is now at the University of Utah on an engineering experiment station fellowship.

Following graduation from Carnegie Institute of Technology in June, **Charles E. Clinton, Jr.**, has accepted a position as sales engineer trainee with the Mesta Machine Co., West Homestead, Pa.

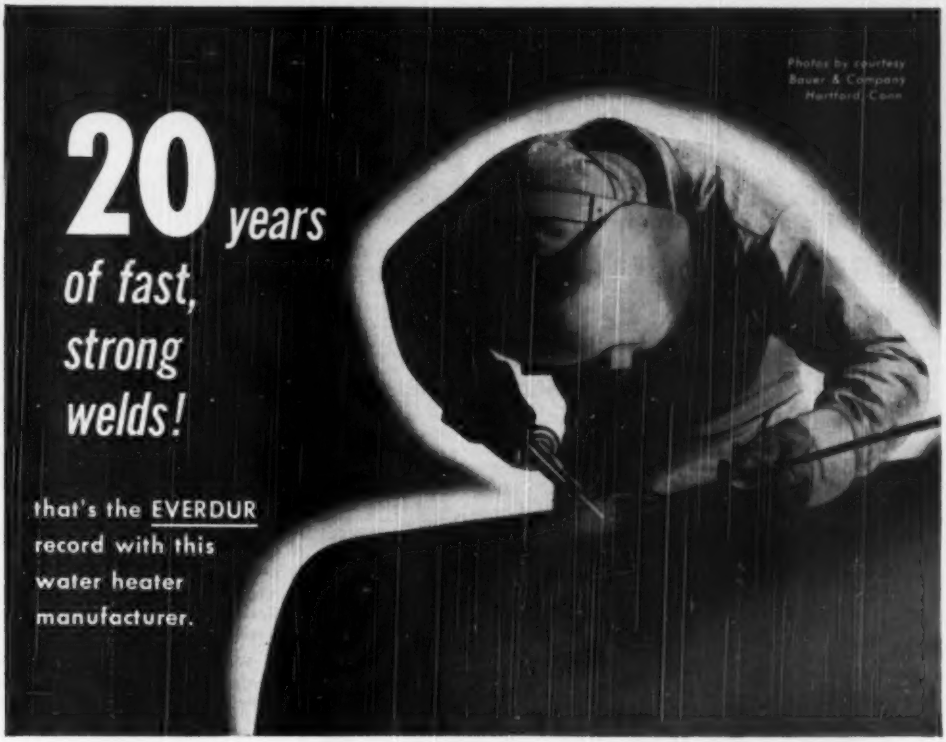
Raymond H. Hays, who has been on leave from the Caterpillar Tractor Co., Peoria, Ill., to receive his M.S. degree at the University of Kentucky, has returned as physical metallurgist.

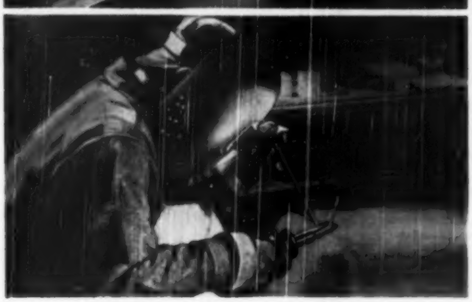
Howard Heineke, a June graduate from the University of Kentucky, has accepted a position as junior engineer in the mechanical engineering department, Bendix Aviation Corp., Kansas City, Mo.

William R. Holman has accepted a position on the staff of Stanford Research Institute as a physical metallurgist.

Martin Jacobson, a June 1950 graduate from Case Institute of Technology, is now a welding research engineer at Battelle Memorial Institute, Columbus, Ohio.

William C. Long, formerly metallurgist at Delco Products Div., General Motors Corp., and member of the A.S.M. Dayton Chapter executive board, is now sales representative for the Reynolds Metals Co., Aluminum Div., in the Detroit office.





IN 1928, Bauer & Company, Inc., Hartford, Conn., started using Everdur* Welding Rod and Everdur Sheet in water heater tank production . . . and they still do.

After all these years, they are more than ever convinced that Everdur Welding Rod is ideal for fast, dependable welding on this type of work.

For Bauer welds simply *have to be* dependable—because every Bauer Water Heater Tank is guaranteed for 20 years.

While carbon-arc welding is the method they use, Everdur can be welded with Everdur Rod by other standard techniques and equipment.

Want more information? Write for Publications B-13 and E-13. All ANACONDA Welding Rods are available from distributors throughout the United States. The American Brass Company, Waterbury 20, Connecticut. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario.

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1. *Welding forged Everdur flange to tank body.*
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3. *Welding Everdur tank head to body.*

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Personals

Fred E. Storm, previously a process metallurgist for the research department of Chase Brass & Copper Co., has been appointed a tool and steel metallurgist for the Waterbury, Conn., division of the company.

James S. Sutterfield has been transferred by Boeing Aircraft Co., Wichita, Kan., from heat treater to the inspection department.

Henri P. Tardif, who received his M.Sc. from Carnegie Institute of Technology in June, has returned to the physical metallurgy research laboratories of the Department of Mines and Technical Surveys, Ottawa, Canada, as metallurgical engineer.

Earle Thall, who was with the Ontario Research Foundation's department of engineering and metallurgy, has joined the staff of the University of Toronto as a lecturer in metallurgy.

Wm. K. Stamets, Jr., has recently been appointed chief engineer, Enterprise Co., Columbiana, Ohio.

R. F. Thomson, formerly in the development and research division of International Nickel Co., Detroit, is now associated with the Research Laboratories Div., General Motors Corp., as head of the metallurgy department.

Arthur H. Tuthill, formerly group leader in the equipment inspection department of Esso Standard Oil Co., is now engineering materials consultant, engineering department, E. I. Du Pont de Nemours & Co., Inc., Wilmington, Del.

Kenneth T. Wilbur, who received his Met. E. degree from the University of Cincinnati in August, has joined the new Automatic Transmission Plant of the Ford Motor Co., Cincinnati, Ohio, as a metallurgical technician.

Jessop Steel Co. announces the transfer of **E. Roy Wildeman** to the position of district manager of New England territory with offices in Hartford, Conn. He had previously been in the New York and Chicago offices.

R. T. Thurston, who recently received his metallurgical engineering degree from Massachusetts Institute of Technology, is now employed as assistant metallurgist by American Manganese Steel Div., American Brake Shoe Co., Chicago Heights, Ill.

VANCORAM BRAND

Products for the Iron and Steel Industries

PRODUCT	TYPICAL COMPOSITION	APPLICATIONS
ALSIFER	Aluminum......20% Silicon..........40% Iron...........40%	Used principally as a steel deoxidizer and for grain size control.
FERRO CHROMIUM High Carbon Grade	Chromium....66-70% Carbon.........4-6%	For wrought constructional steels and steel and iron castings.
Iron Foundry Grade	Chromium....62-66% Carbon.........4-6% Silicon.........6-9%	For alloyed cast irons. Readily soluble as a ladle addition at the lower temperatures of cast iron.
Low Carbon Grades	Chromium....67-72% Carbon...06%, .10%, .15%, .20%, .50%, 1.00% and 2.00% max.	For low carbon chromium steels, especially those with high chromium content, such as stainless and heat resistant types.
FERRO SILICON 25-30% Grade	Silicon.......25-30%	Deoxidizer for open hearth steels; also for high silicon, corrosion-resistant iron castings.
50% Grade	Silicon.......47-52%	Used as a deoxidizer and for the addition of silicon to high silicon steels, for springs, electrical sheets, etc. Pulverized form used as ladle addition to cast irons for silicon content and graphitization control.
75% Grade	Silicon.......74-79%	For high content silicon steels, such as spring steels, sheets and forgings of high magnetic qualities for electrical apparatus.
High Silicon Grades 80-85% 85-90% 90-95%	Silicon.....80-84.9% Silicon.....85-89.9% Silicon.......90-95%	For high content silicon steels where small ladle additions are used for required silicon content. Also for manufacture of hydrogen by reaction with caustic soda and production of magnesium by the Pidgeon process.
FERRO TITANIUM High Carbon Grade	Titanium.....15-18% Carbon.........6-8%	Final ladle addition to control "rimming" action and to clean effervescing steel. Final deoxidizer and scavenger for steel castings and fully killed ingot steels.
Medium Carbon Grade	Titanium.....17-21% Carbon......3-4.50%	Often preferred to the High Carbon Grade as a final ladle addition to very low carbon rimming or effervescing steels.
Low Carbon Grades 20-25% Ti Grade	Titanium.....20-25% Carbon...max. 0.10% Silicon......max. 4% Aluminum max. 3.50%	Carbide stabilizer in high chromium corrosion-resistant steels of extremely low aluminum content. Deoxidizer for some casting and forging steels.
40% Ti Grade	Titanium.....38-43% Carbon...max. 0.10% Silicon......max. 4% Aluminum...max. 8%	Carbide stabilizer in high chromium corrosion-resistant steels, where smaller ladle additions are desired and extremely low aluminum content is not essential.
ALUMINUM	Aluminum ... 85-99%	For deoxidation and grain size control of steel. (Ingot, shot, grain and special shapes.)
VANADIUM METAL 90% Grade 95% Grade 99.7% Grade	Vanadium ...... 91% Vanadium ...... 95% Vanadium 99.7%	For iron-free, low-iron, or low-impurity alloys.
FERRO VANADIUM Iron Foundry Grade	Vanadium....38-42% Silicon.........7-11% Carbon.....about 1%	For iron foundry use. Imparts remarkable improvement in physical properties with no sacrifice of machinability; highly soluble, insuring complete diffusion.
Grade "A" (Open Hearth)	Vanadium....35-45% 50-55% Silicon....max. 7.50% Carbon....max. 3.00%	For low percentage vanadium content of rolled, forged or cast constructional steels. Also used in vanadium cast irons.
Grade "B" (Crucible)	Vanadium....35-45% 50-55% Silicon....max. 3.50% Carbon....max. 0.50%	For tool steels and special high vanadium steels in which required limits for carbon and silicon are narrow.
Grade "C" (Primos)	Vanadium....35-45% 50-55% 70-80% Silicon....max. 1.25% Carbon....max. 0.20%	For tool steels and special steels requiring high percentages of vanadium and exceptionally low carbon and silicon content.
VANADIUM PENTOXIDE Technical Grade Fused Form	V_2O_5..88-92%	A source of vanadium in basic electric furnace steels. A base for numerous chemical compounds.
Technical Grade Air Dried Form	V_2O_5.......83-85%	A base for preparation of numerous chemical compounds (catalysts, etc.).
GRAINAL ALLOYS Vanadium Grainal No. 1	Vanadium....25.00% Aluminum....10.00% Titanium.....15.00% Boron.........0.20%	Practical and economical intensifiers for controlling and increasing the capacity of steels to harden, and for improving other important engineering and physical properties.
Vanadium Grainal No. 6	Vanadium....13.00% Aluminum....12.00% Titanium.....20.00% Boron.........0.20%	See above.
Grainal No. 79	Aluminum....13.00% Titanium.....20.00% Zirconium.....4.00% Manganese....8.00% Boron.........0.50% Silicon.........5.00%	See above.
GRAPHIDOX No. 4	Silicon .... 48-52% Titanium ...... 9-11% Calcium 5-7%	For graphitization of iron; ladle treatment insures normal graphite, free from dentritic structure; reduces chill; efficient inoculant in production of high strength irons.
V-FOUNDRY ALLOYS V-5 Grade	Chromium....38-42% Silicon.......17-19% Manganese....8-11%	Used in cast irons as a ladle addition. Reduces chill, promotes uniformity of structure, increases strength and hardness.
V-7 Grade	Chromium....28-32% Silicon.......15-21% Manganese...14-16%	See above.
BRIQUETTES Ferro Chromium	Hexagonal. Weigh approx. 3¾ lb. and contain 2 lb. of chromium.	A practical and convenient form for adding ferro-alloys to the cupola.
Ferro Silicon	Two sizes, both cylindrical, one containing 1 lb. of silicon; the other, 2 lb. of silicon.	See above.
MISCELLANEOUS	Special ferro-alloys, metals, chemicals and carbides.	To meet individual requirements.

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Personals

Tracy C. Jarrett ⊕ has been appointed midwest representative for C. I. Hayes, Inc., Providence, R. I. Dr. Jarrett was previously manager of the engineering and research department of the Piston Ring Div., Koppers Co., Baltimore, Md.

T. B. Jefferson ⊕, editor of *Welding Engineer* and the "Welding Encyclopedia", has been appointed to the advisory committee of the Welding Institute at the Milwaukee School of Engineering.

Carl A. Keyser ⊕ has been promoted from assistant professor to associate professor of metallurgical engineering, University of Massachusetts.

Ira S. Latimer ⊕, formerly with the Plymouth Steel Co., has been appointed Detroit district representative for Industrial Forge & Steel, Inc., Canton, Ohio.

William E. L. Smith ⊕, who graduated from Virginia Polytechnic Institute in June, is now a metallurgist with the Du Pont Co. at the Belle, W. Va., plant.

W. J. Lawler ⊕ has recently joined the plant metallurgical staff of Kaiser Aluminum & Chemical Co., Trentwood, Wash.

Paul E. Crafton ⊕ has been recently appointed Chattanooga, Tenn., district sales engineer for the F. J. Evans Engineering Co., and will sell Surface Combustion Corp. and Webster Engineering Co. products.

Henry E. Frankel ⊕, formerly employed by the Metals Research Laboratory of Carnegie Institute of Technology, is now with the Naval Research Laboratory, Washington, D. C.

Harold M. Gordon ⊕ is presently employed by the Aluminum Co. of Canada as a supervisor at the Shawinigan Falls, Quebec, plant.

William C. Greenleaf ⊕, formerly stainless steel metallurgist at Allegheny Ludlum Steel Corp., has been transferred to metallurgist for titanium metals, sheet and strip at the Brackenridge and Leechburg, Pa., plants.

Charles Grell ⊕, who graduated from Carnegie Institute of Technology in June, is now employed in the melt shop of the Timken Roller Bearing Co.'s sheet mill at Canton, Ohio.

An EF Gas-Fired Radiant Tube Furnace for bright annealing wire. The secondary burner tubes, which are subjected to the highest temperatures, are made of Inconel. Built by The Electric Furnace Company, 425 Wilson St., Salem, Ohio.

EF FURNACES, TOO...

Built with INCONEL for long life at high temperatures

Twelve years ago, the Electric Furnace Company conducted a series of tests to discover the best possible metal for secondary burner tubes in their gas-fired, radiant tube furnaces.

Inconel® won, and is still a winner, today, in the hottest parts of EF recuperative radiant tubes ... in several critical parts of the assembly.

In addition to long, trouble-free service assured by Inconel, EF claims other important design features for their radiant tube furnaces ... tubes that are removable even while furnace is operating ... increased burner efficiency through pre-heated air ... more compact tubes ... uniform heating over entire tube length.

Like many other leading makers of high-temperature equipment, the Electric Furnace Company has adopted Inconel as a *standard* metal for extreme high heat applications.

Inconel's outstanding performance record long ago established it as one of the most durable high-temperature metals available to designers.

Highly resistant to destructive oxidation, Inconel maintains good properties at temperatures up to 2200°F. Welds in Inconel are as heat- and corrosion-resistant as the alloy itself.

The Electric Furnace Company, 425 Wilson St., Salem, Ohio, will be glad to answer your inquiries concerning EF furnaces for any process, product or production.

If you would like more information about Inconel ... and help with your high-temperature equipment problems, write directly to Inco.

EMBLEM OF SERVICE INCO

THE INTERNATIONAL NICKEL COMPANY, INC.

67 Wall Street, New York 5, N. Y.

Personals

Armour Research Foundation of Illinois Institute of Technology announces the appointment of **Walter C. Troy** as assistant chairman of the metals research department. Mr. Troy has been with the foundation since 1947.

Battelle Memorial Institute announces the appointment of **Godfrey B. Grable** to its welding research staff. Mr. Grable was formerly associated with the Bureau of Ships, the Bureau of Aeronautics and the A. O. Smith Corp.

Wyandotte Chemicals Corp., Wyandotte, Mich., announces that **Sidney Grandy** has joined its sales staff and will have his headquarters in Atlanta, Ga.

Frank A. Hamilton has recently been appointed acting tire and forge plant superintendent of Commonwealth Steel Co., Ltd., Waratah, Australia. He was formerly a technical representative in the company's Sydney office.

W. A. Hammer, formerly plant metallurgist for St. Louis plant of Lindberg Steel Treating Co., has been appointed plant metallurgical engineer at the Houston, Tex., plant of Emsco Derrick & Equipment Co.

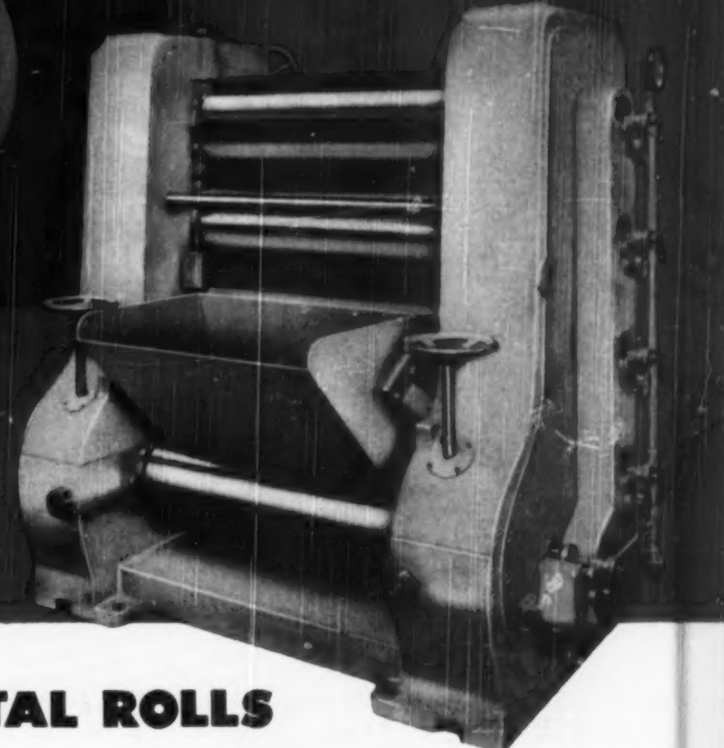
William M. Harris, who received his B.S. from Missouri School of Mines and Metallurgy in 1950, has been appointed an instructor in the department of mechanical engineering at this school.

W. L. Gilliland has resigned as professor of chemistry at Purdue University to go into business as a consulting chemist, and he is opening a research laboratory in Lafayette, Ind.

Following graduation from Missouri School of Mines and Metallurgy, **John W. Gilmore** has been employed by the Howell Foundry Co.

Stephen L. Scheier, former forging superintendent for Columbus Bolt & Forging Co., has accepted a position as superintendent with Storms Drop Forging Co., Springfield, Mass.

E. M. Sherwood, past chairman of the New York Chapter of the American Society for Metals, has left his former position of project engineer in the armament division of Sperry Gyroscope Co. to become a research engineer at Battelle Memorial Institute, Columbus, Ohio.



DUAL METAL ROLLS

Centrifugally cast dual metal roll shells have found wide acceptance with equipment builders who use chilled iron rolls for grinding or processing such commodities as ink, paint, pigments, chocolate, paper, flour, cereals and soap.

One of these equipment builders is the J. M. Lehmann Company, Inc. of Lyndhurst, New Jersey, who has standardized on our centrifugally cast dual metal chilled iron-gray iron rolls for their soap, ink and chocolate mills which they identify as "CDM" Rolls (centrifugally cast dual metal), a Lehmann trademark.

Utilizing centrifugal force and temperature, our dual metal casting process makes possible the production of grinding and processing rolls requiring a hard outer shell of white iron for the wearing surface and a soft, readily machinable gray iron core to facilitate the insertion of driving shafts. These two dissimilar metals are cast separately but are metallurgically bonded so as to provide an *accurately controlled and uniform chill depth and also uniform hardness* in both the hard outer shell and the soft gray iron core.

A number of two-metal cylindrically shaped combinations are now being made for equipment manufacturers who require metallic structures which have two working surfaces and where performance requirements imposed on these surfaces are quite dissimilar.

[illegible]

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Hot Working of Tin Bronzes*

THE AUTHOR has examined the influence of various factors on the hot working of phosphorized tin bronzes. Both theoretical and commercial aspects are considered, and presentation is based on a review of publications plus personal observations. Five diagrams and thirteen references are cited and used in discussion.

Until the late 1920's there is no reference of importance to the hot working of phosphor-tin bronzes, although some companies were doing it with alloys containing less than 3% tin. More recently the work of Lepp, Pell-Walpole, Chadwick and others has indicated the importance of porosity, tin sweat and impurities on working properties.

The copper-tin equilibrium diagram reveals no reason for difficulty in hot rolling, at about 700° C., up to about 15% tin, but the alpha phase appears to lose ductility with increasing temperature and the addition of phosphorus produces a liquid phase at temperatures around 650° C., varying with the amount of tin and phosphorus. The latter must be kept low for hot working, which is difficult for the above reasons.

High-grade copper of at least 99.92 assay should be used, and tin selected with particular care. Marked improvements have resulted from the use of Chempur tin. By analogy to phosphorus-deoxidized nonarsenical copper it is reasoned that phosphorus-deoxidized tin bronze will crack up in hot rolling if lead exceeds 0.02% or bismuth 0.0015%. Antimony would also have an effect. No limits for these impurities have been published for tin bronze but it is unlikely that the addition of tin to copper would remove their embrittling effects.

It is suggested that, when conditions of casting are such that pronounced tin sweat occurs, lead, bismuth, antimony or other impurities may be carried along with the low-melting copper-tin phase, as ternary or quaternary eutectics, and settle intergranularly near the surface. Hence, gas-free castings without porosity of any sort are less sensitive to impurities. (To p. 892)

*Abstracted from "The Hot Working of Tin Bronzes", by D. W. Dugard Showell, *Journal*, Institute of Metals (London), Vol. 76, 1950, p. 527.

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Hot Working of Tin Bronzes

(Cont. from p. 890) This hypothesis requires more work, but there is evidence to confirm it. Degassing the melt, followed by slow pouring, calculated to prevent tin sweat, produces a bronze that is sounder and more easily worked than that on which tin sweat occurs.

Chadwick has investigated the hot forging of small cylinders — a very severe test because the metal is unsupported. Using sound, degassed metal, charts indicate the range from 0 to 0.5% phosphorus, from 0 to 30% tin. With 0.10% phosphorus, up to 6% tin, reasonable forging was possible up to 800° C. From about 6 to 13% tin, the metal tended to crack above 350 to 400° C. From 20 to 30% tin, bronze was very tough in a rather narrow temperature range near 650° C., although unworkable cold. With 0.5% phosphorus, all bronzes with more than about 3% tin cracked above about 400° C.

Hot rolling of 1% tin bronze, with a trace of deoxidant, is easy up to 850° C., and 5% tin with 0.05% phosphorus rolls satisfactorily at 600 to 650° C. The upper temperature limit is important and should not be exceeded. If overheated and cooled before hot rolling, cracking will result. Vertical castings up to 3 tons, with 7% tin and 0.10% phosphorus can be hot rolled with light reductions down to black temperature. On reheating, temperature can be increased to 650 or 700° C. Soaking at hot working temperature is always desirable.

Extrusion is commercial with bronzes up to 8% tin and 0.25% phosphorus. The extrusion rate must be slow, and the operation depends on the power of the press and the size of the product. The temperature range is narrow, being limited on the upper side by that at which the metal crumbles on emerging from the die, and on the lower side by that at which the pressure required is greater than available.

Abstracter's Remarks — There is little in this work with which one can disagree. The degassing process and any measures to minimize inverse segregation are, beyond question, beneficial to hot (or cold) rolling properties. But I think it doubtful if all the gas is ever removed, or that *(Ends on p. 894)*

Hot Working of Tin Bronzes

(Starts p. 890) inverse segregation is ever entirely prevented. The influence of impurities is also acknowledged to be important and, for hot rolling, I would place the limit of tolerance for lead at something less than 0.01%, rather than 0.02%.

When all is said, the bare fact emerges that the phosphor bronzes in the upper alpha range are not very good hot working alloys. They can be extruded, that being the simplest form of hot work. Up to about 3% tin, they can be hot strip rolled readily enough and, with increasing difficulty, up to 5 or 6% tin. But the alloys between 5 and 10% tin are important to the rolling mill, and no amount of metallurgical legerdemain has yet succeeded in making this a really good, commercial, hot rolling range. To do so would be an epochal accomplishment.

DANIEL R. HULL

A Britisher Comments on American Welding*

TEAMS of British businessmen, foremen and labor leaders from this, that or the other industry have been brought to the United States by the Economic Cooperation Administration, to study our methods of manufacture and sale. On returning home from their inspection trips, these teams prepare reports for general circulation giving their impressions and recommendations. This report by Mr. Simmie is of such a nature, and compares current practices in England and America in the welding of mild steel by resistance methods. It applies primarily to the automotive industry but also includes some references to the manufacture of domestic appliances.

It is estimated that demand for resistance welding equipment in America is probably *(To p. 896)*

*Abstract of "The Resistance Welding of Mild Steel Sheet", by W. S. Simmie, *Journal* of the American Welding Society, August 1950, p. 651-654.

In medieval times, a coat-of-arms had an importance that could not be overestimated. It was granted as a personal badge, signifying the attributes and accomplishments of its proprietor—and as such was respected thruout the civilized world. It had no duplicate.

In turn, the emblem imposed upon its owner a responsibility for maintaining an enviable reputation—a condition which stimulated general confidence in him.

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It is evidence of our accomplishment; our unique, personal badge — respected everywhere. Granted solely and wholly to us by the United States Patent Office over forty years ago, it symbolizes a series of superb electrical heat and corrosion-resistant alloys (developed and produced *only* by Driver-Harris Company) which today is serving industry all over the world.

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Resistance Welding

(Starts on p. 894) ten times that in Britain, and this results in larger funds being available for research and development. One result is the American development of three-phase resistance welding equipment and "slope control" of the amplitude of the welding current wave, which is of considerable interest to British users of resistance welding because of their limitations of power supply. During the past few years governmental assistance to British research associations has helped to encourage developments.

Large, multiple spot welders and automatic seam welding machines, commonly used in America, are now being introduced in Britain. Previously the use of such equipment has been very limited because of low production demands and lack of adequate power supply for this type of load.

In Britain much study has been devoted to the factors affecting uniformity of strength of spot welds in order to obtain consistency and conserve on the number of spot welds required to meet design requirements.

British automotive manufacturers have endeavored to maintain a consistent spot weld strength with a specified minimum weld pitch value (spacing) in production by:

1. Using interlocking devices in the control system of the welding machine.
2. Controlling electrode tip size.
3. Eliminating automatic repeat operations.

The use of interlocking devices facilitates automatic functioning of the welding control system and prevents interference by the operator during the weld cycle, but tends to slow down the speed of welding. On air-operated machines this reduction in speed can be minimized by locating the main exhaust valve close to the main operating air cylinder. In some American installations the author observed that this interlocking control was incorporated in the weld timer mechanism and the speed of operation could be varied by a rheostat. The rheostat was often set at zero to obtain maximum speed; thus it appeared that the quality of weld was being disregarded.

More attention is paid by us to the electrode tip diameter. However, workmen in some American factories frequently *(To p. 898)*

Resistance Welding

(Starts on p. 894) redress the tips with a standard file. In Britain several types of tip dressing tools are available. One of the most recent, consisting of two files fixed in a holder at a specified angle, is approved, since it avoids excessive waste of the tip material.

Some British factories have discarded controls which cause the welding unit to repeat the spot welding cycle. The operator can then place the welding unit and the weld so as to obtain proper weld spacing. High production speeds can still be maintained without these automatic control features.

The method of spot welding known as "poke welding" is rarely used in Britain, although it is in some American factories. The British regard it as unsatisfactory because of the variable weld strength obtainable and lack of adequate control.

Where a spot weld must be made with a minimum of metal disturbance or indentation on the surface of one member, this is termed "face welding" in British parlance. Sometimes it avoids finishing operations. It is accomplished by the use of chromium-copper buttons installed at desired intervals in the assembly jigs. These buttons, which are readily replaceable, have a blind hole drilled in the lower face to locate the lower welding electrode tip; the top face of the button, usually flat, has a relatively large area of contact with the member surface which must not be marred by the weld. No comment is offered with reference to American practice in this respect.

In face welding thin steel sheet to thick steel frames, a series of holes is punched in the thick frame at the desired spot weld locations. Into these holes are inserted steel buttons of thin-gage sheet, which have a flanged skirt around their rim. This flanged skirt is spot welded to the thick member. Then the outer thin sheet is applied to the steel frame and face welded to the thin steel buttons. This procedure avoids concentration of the welding current through the thick member.

For priming the metal surfaces of spot welded members to obtain an efficient protective coating, a new type of paint has been developed in Britain. *(Cont. on p. 900)*

Technical and business papers are full of articles pointing out new uses for stainless steels. The many friends of stainless are apt to overindulge in its praise . . . no matter what the application might be.

Crucible, a pioneer in the development of this specialty steel, is well aware that stainless will live up to its reputation *only* when the right stainless analysis is used. That's why Crucible offers the services of a staff of metallurgists to help you apply stainless to your application.

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Resistance Welding

(Starts p. 894) This paint contains zinc dust in suspension. When dry this paint does not interfere with subsequent spot welding of the surface it covers.

Solder is used in Britain for filling welded seams to obtain a smooth surface for finishing. More recently, metal spraying of zinc was introduced for welded butt joints. Zinc is sprayed after all straightening operations are completed and the line of weld to be sprayed has been shot blasted. A final disking operation completes the process. It is reported that American practice involves Heliarc welding in which the weld may be peened flat and so avoids the use of any filling metal in the joint.

The author states that "the automobile industry is the largest user of resistance welding equipment in Britain and the introduction of the unitary-chassis body construction has been largely responsible for the demand for a higher standard of consistency and uniformity of weld strength. This 'quality' spot welding is now widely used in Britain. In America it has been introduced in some factories but, generally speaking, it does not appear to be used on such a large scale."

William L. Warner

Creep of Copper*

SEVERAL theoretical questions of importance remain unanswered in the mechanism of creep — that is, the gradual slow extension of metal under moderate tensile stress when at somewhat elevated temperature. Some of these questions center in the relations between the strain hardening caused by the plastic extension, the "recovery", and the changes in microstructure that occur during the different stages of creep. The supposed mechanism involves discontinuities in the extension versus time curve. That is, there should be a delay in time while relaxation proceeds until sufficient stress is concentrated in (Cont. on p. 902)

*Abstract from "Creep of High-Purity Copper", by W. D. Jenkins and T. G. Digges, National Bureau of Standards Research Paper No. 2121.

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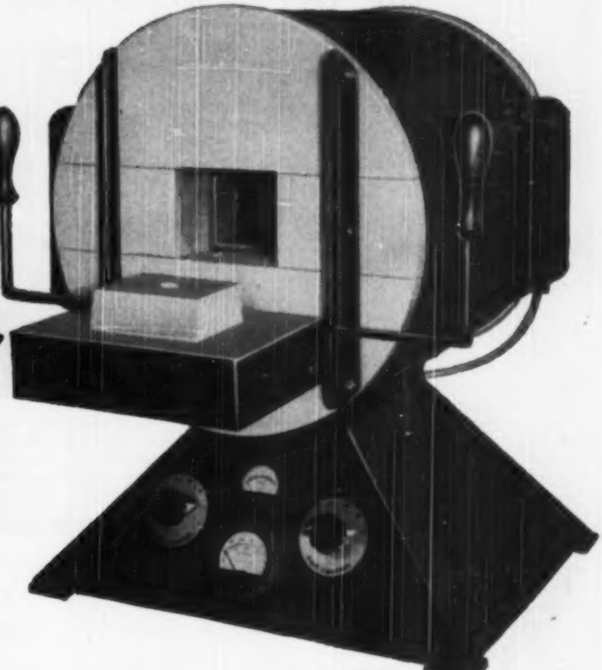

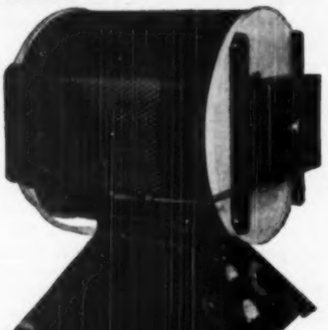

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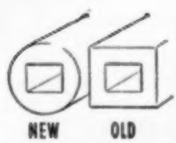

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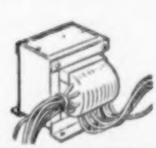

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Creep of Copper

(From p. 900) other regions to reinitiate flow. The periods of time during which the test specimen undergoes no appreciable extension or actually contracts (negative creep) should be readily detectable in precision testing.

Such discontinuities were actually observed in previous creep tests made on ingot iron (a strain aging material) and in some current tests on high-purity copper.

These discontinuities and their importance varied not only with the temperature and stress, but also with the progress of the test, being more prominent in the second (uniform) stage of creep than in either the first or third stage. The metallic structure continually changes; the parent grains broke down into subcrystals, some of which were of microscopic dimensions. The extent to which the substructure was formed also varied with test conditions; the trend was for the size of these secondary crystals to increase with an increase in temperature and with a decrease in strain rate. Strain markings were evident in all fractured specimens.

Formation of cracks of microscopic dimensions often accompanied but was not necessarily a prerequisite for the initiation of the third stage of creep in the high-purity copper. Positions at which these cracks were nucleated and their subsequent growth were affected by the test temperatures and strain rates. Sometimes cracks started near the axis of the test specimen; in other specimens cracking commenced at the surface.

Radioactive Sodium as a Metallurgical Tracer*

SEVERAL divergent theories have been proposed to account for the change in microstructure when aluminum-silicon *(Cont. on p. 904)*

*"Modification in Aluminum-Silicon Alloys", by B. M. Thall and Bruce Chalmers, *Journal* of the (British) Institute of Metals, V. 77, part I, 1950, p. 79.


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Radioactive Sodium

(Starts on p. 902) alloys have very small additions of alkaline metals or their fluorides. The notable improvement in physical properties has indeed been responsible for commercial uses of these "modified" alloys.

Since a 10% silicon alloy can be modified with as little as 0.1% of sodium, added to the melt, and since quantitative analytical methods for such small amounts of sodium are not too precise, there has been reason to doubt whether any of this highly volatile metal remained in the solid alloy. To check this point, the authors made up a series of alloys and exposed samples of each to radiation in the uranium pile at Chalk River, Canada. The radioactivity so induced in the major constituents, aluminum and silicon, is of short life; the artificial radioactive isotope Na^{24}, however, has a half-life of 14.8 hr.

The authors made periodic checks on the emissions from the irradiated alloys, using a Geiger-Müller counter of high sensitivity. Allowing for the background radiation (that is, the radiation detected when no specimen is in front of the counter) and for the radiation from the blank (that is, from an irradiated 10% Si-Al alloy to which no sodium had been added and which possessed the "normal" eutectic plate microstructure), the counts from the irradiated modified specimens decreased at a rate corresponding to a half-life of 14.8 hr. It was therefore concluded that sodium, despite its volatility, is indeed retained in the modified alloys when solidified.

Without attempting to show any quantitative relation between the observed radioactivity and the sodium content of the individual samples, certain qualitative statements can be made: *(a)* Sodium is retained in all alloys to which it was added when molten. *(b)* The amount retained is proportionate to the amount added and to the rate of solidification. *(c)* Remelting loses some but not all of the sodium, and superheating increases this loss.

The contribution ends with a new theory for the modification mechanism, and a note calling attention to the analogy with the production of nodular cast iron (cast iron "modified" by small amounts of magnesium or cerium).

German Steels*

As noted in the section of this abstract dealing with production [*Metal Progress* for April, p. 508] large tonnages of steels formerly made in basic openhearth furnaces in Germany were made in basic converters during the war. In the low-alloy constructional steels made in the basic openhearth furnace, special care was taken to achieve low sulphur and phosphorus contents of the order of 0.010 to 0.025%. This greatly assisted the alloy conservation measures and resulted in a large tonnage of steel having a high degree of "cleanness".

In alloy steels for heat treating, scarcities of alloying elements led to conservation measures as follows: First, when nickel was scarce, chromium-molybdenum and chromium-molybdenum-vanadium steels were employed. Next, as the molybdenum supply became more difficult, the former steels were largely replaced by chromium-vanadium and manganese-vanadium steels. Then chromium became scarce and manganese steels were put to greater use, together with higher silicon contents. Periodically the specifications for a given steel were revised and the alloy contents were so pared down that the steels had to be especially "clean" and of high purity in order to satisfy mechanical test requirements.

In addition to the mandatory substitution of spiegeleisen instead of ferromanganese wherever possible, other measures had to be taken to assure supplies of manganese. Manganese ore in the blast furnace charge was replaced by bessemer slags, together with slag from blast furnaces making spiegel. Also, deoxidation had to be carried out largely by the use of anthracite and powdered coke in the furnace, together with varying amounts of ferrosilicon and ferro-aluminum added in the ladle.

The principal means of lowering the net national consumption of manganese was the adoption of the Brassert or *(Continued on p. 908)*

*Abstract from "The Ferrous Metal Industry in Germany During the Period 1939-1945", by George Patchin and Ernest Brewin, Over-all Report No. 15 of the British Intelligence Objectives Subcommittee; obtainable from British Information Service, 30 Rockefeller Plaza, New York City 20. ($1.15.)

German Steels

(*Starts p. 906*) acid smelting process, supplemented by other changes in blast furnace practice, such as increasing the fluidity of the slag by adding alumina, and by boosting the silicon content of the pig iron.

Substantial amounts of manganese were recovered from unconventional sources through the medium of high-manganese slags reduced either by the Ischebeck process or the Hahl-Rosenbaum process. Matte smelting of manganiferous iron ores was not attempted. Slags resulting from the processes mentioned contained 30 to 35% Mn and were well-suited for use in the production of spiegel.

The economic control of alloying elements had a marked effect on the composition of alloy and special steels, which in turn reacted on mechanical design and methods of construction.

Alloys for Use at High Temperatures — German metallurgy, in general, was not comparable in achievement to German turbine engineering, and the best newer steels and alloys available in Great Britain and the United States outclassed the corresponding German ones.

In order to balance the deficiency in suitable alloys for gas turbines, the Germans developed ingenious designs, applying air cooling to hollow turbine buckets and even considered water cooling to reduce operating temperatures.

Combustion chambers and nozzles were made originally from steel with 0.12% C, 0.80 to 1.10% Si, 0.20 to 0.40% Mn, 0.40 to 0.70% Al, 6.3 to 6.8% Cr. These units, however, were manufactured subsequently from low-carbon deep drawing sheets, surface treated in various ways to increase their resistance to scaling. Chromizing, aluminizing or aluminum lacquers were used for this purpose with fair success.

Stainless Steels — Owing to the shortage of alloying elements, the use of stainless steels in Germany was restricted to essential applications, and there had been little new development. The stainless steel used for destroyer, U-boat and speedboat propellers was Krupp P.125, as follows: 0.12% C, 1.7% Si, 0.7% Mn, 7% Ni, 23% Cr. Shaft liners of 12.5 to 13.5% Cr steel (forged or centrifugally cast) had given good service as an alternative to bronze. (*Continued on p. 910*)

German Steels

(Starts on p. 906)

The use of compound sheets (mild steel backing and stainless steel surface) grew considerably during the war as a result of the general shortage of alloying elements, and such sheets, with a stainless surface on one or both sides, were produced down to a minimum total thickness of 0.118 in.

High Speed Steels — Before the outbreak of war the standard 18-4-1 high speed steel had been replaced by the following:

	C	W	Cr	V	Mo
ABC	0.80	9.50	4.50	1.50	0.50
D	0.85	11.00	4.50	2.50	0.50
E	1.40	11.50	4.50	2.50	1.00

Brand ABC was replaced in 1940 by *Dreierstahl* with the following composition:

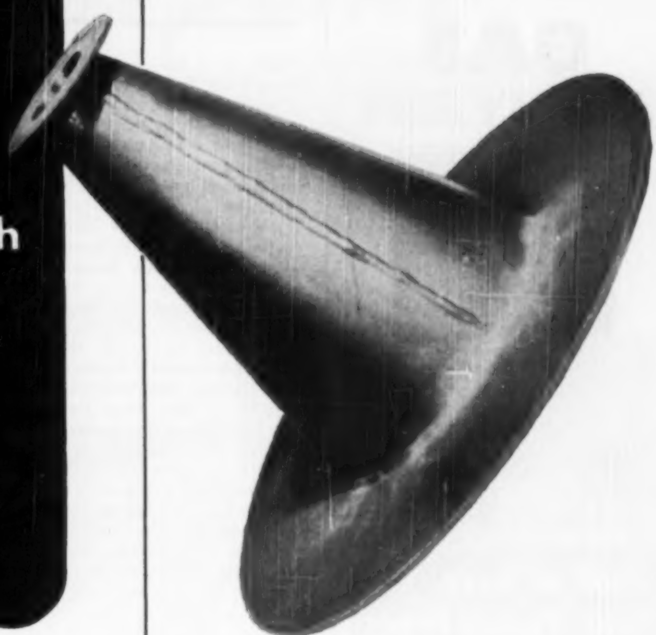
C	W	Cr	V	Mo
0.90-1.00	2.50	4.00	2.50	2.50

At the end of 1944, molybdenum became more scarce than tungsten and, to conserve stocks, the *Dreierstahl* was cancelled.

Those who manufactured *Dreierstahl* were enthusiastic regarding its performance. It was stated that it averaged about 20% better than a standard 18% tungsten high speed steel for general applications. It was admitted, however, that it was sensitive to grain growth and must be heat treated within narrow temperature limits. The usual recommended quenching temperature was 2265° F., with a tempering temperature of 1015° F., double tempering being standard practice with this steel as with all other high speed steels. Krupp manufactured this steel with an addition of 0.05 to 0.10% Ti, apparently with the object of reducing susceptibility to grain growth.

Die Steels — Toolsteels for hot work appeared to follow American practice, but with a much wider range of compositions. Tungsten was definitely favored as an alloying element for most hot work die steels, and a composition with 4.5% W and 1.5% Cr, made in several carbon ranges from 0.24 to 0.45%, was widely used.

Steel of the class long used by most countries for airplane engine exhaust valves, 0.25 to 0.45% C, 13.0 to 15.0% Ni, 13.0 to 15.0% Cr and 2% W, was also used for hot extrusion dies. This was forged or rolled to billets, then slugs were cut and finished into disks *(Cont. on p. 912)*



German Steels

(Starts on p. 906) by heating to about 1830° F. and forging so as to strike the last blows when the steel was as cold as 1240° F. In this method of cold finishing or "hammer hardening", the final temperature depended on the desired hardness.

Ferro-Alloys — The German industry was based mainly on electric furnace production (even in such cases as production of ferrotungsten and ferromolybdenum). A notable wartime development was the extent to which the ferrovanadium output from slag had been forced. The maximum figure claimed to have been reached in that country as a whole was 300 tons of ferrovanadium per month in 1944, as compared with 60 tons per month before the war. The oxide was reduced almost entirely by aluminothermic processes, although a little "ferro-carbon-vanadium" was made electrically in the ferrotungsten furnaces at Weisweiler.

Extrusion Effects*

HYDRONALIUM 43 (4.5% Zn, 3.5% Mg, remainder Al) is usually extruded at about 840° F. and is recrystallized in the process. After solution treatment for 60 to 75 min. at 840° F., water quenching, and aging for 10 days, the alloy has the following properties.

Wire, drawn 32% to 0.300-in. diameter: 70,000 psi. tensile strength, 45,500 psi. yield, 16% elongation.

Sheet, cold rolled to 0.039-in. thickness: 63,000 psi. tensile strength, 40,500 psi. yield, 18½% elongation.

However, a modification of the same alloy containing 0.40% Cu, 0.20% Mn, 0.15% Cr and 0.05% V, extruded, drawn to 0.300-in. wire, and then heat treated, shows 80,000 psi. tensile strength, 59,000 psi. yield, 13% elongation.

The purpose of Siebel's work was to establish the effects of the various additions. *(Cont. on p. 914)*

*Abstract from "Extrusion Effects in Al-Zn-Mg Alloys With 4.5% Zn and 3.5% Mg", by G. Siebel, *Metallforschung*, Vol. 2, 1947, p. 331-340.

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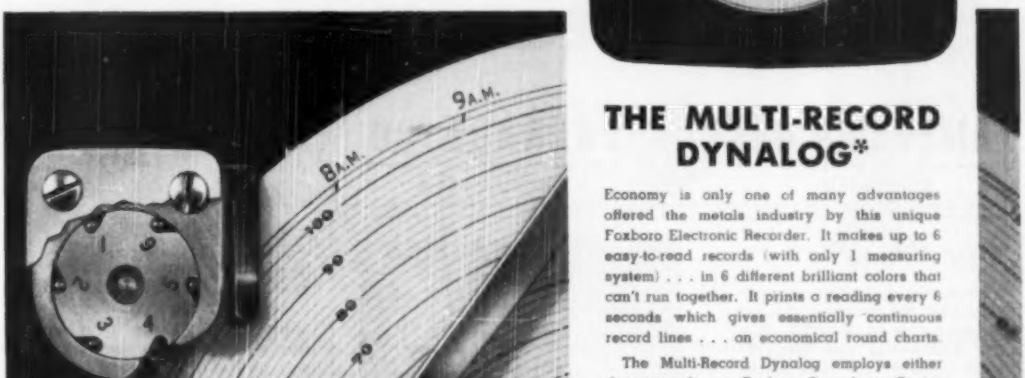

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Extrusion Effects

(Continued from p. 912)

(It is not made clear by the author whether the new variant of alloy Hy 43 was the outcome of this research or whether the tests reported were intended merely to check and explain previous results.) The idea behind the research program was that the additional elements raise the recrystallization temperature so that the extra strength due to the cold worked structure is not lost in subsequent processing.

Several heats containing various amounts of copper, manganese, chromium, vanadium and titanium, added separately, were cast into billets 2.56 in. in diameter and extruded to 0.300-in. wire, which was cold drawn various amounts between 11 and 37%. Temperature of extrusion varied between 715 and 880° F. and the speed from 3 to 10 ft. per sec. The cold drawn wires were given the standard treatment (quenching and aging mentioned at the outset) after quenching from various temperatures.

The results were: Speed of extrusion and temperature used for it have no effect on mechanical characteristics. Copper added to the extent of 1.2% had no effect; neither had titanium or vanadium. Chromium had the strongest effect and was active up to 0.25%; manganese came next, being effective up to 0.5%.

By pickling away the outer layers of the wires, a point was reached beyond which X-ray diagrams revealed an unchanged fiber structure. Temperatures at which fibering disappeared were plotted against the amount of the additional element. It was found that 0.5% Mn shifts the recrystallization temperature from 735 to 915° F. for lightly drawn wires and from 644 to 790° F. for heavy drafts. With chromium the shift was much greater — from 790 to 1060° F., and from 680 to 950° F.

The author does not mention the mechanism of this shift and does not indicate why it was absent for copper, vanadium and titanium. His diagrams show also that the presence of copper causes the action of the other two additions to develop in a much sharper manner; the hardening curve forms a peak instead of running smoothly.

M. G. C.

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BALDWIN TESTING HEADQUARTERS

Cupola Practice

RECENT issues of the British Cast Iron Research Association's *Journal of Research and Development* contain several articles on cupola practice that are of more than usual interest.

Water-Cooled Cupolas* — During the war, the scarcity of foundry iron necessitated increased use of steel scrap in the cupola charge. With high proportions of scrap the lining eroded rapidly and, after various types of neutral and basic brick had been tried without improvement, attention was directed to the possibilities of water cooling.

Examination of the lining of a cupola operating on 95% scrap, revealed maximum erosion along a line 15 to 18 in. above the tuyere. Preliminary trials of water cooling were undertaken about this line as a center, using tanks 30 in. wide fabricated from ¼-in. rolled plate. The experiment showed promise but, during occasional periods when the blast was off, curtains of mild steel formed on the faces of the water jackets and had to be removed with cutting torches when the lining was repaired.

Subsequently experiments were initiated on a 30-in. cupola operating continuously in a mechanized foundry, melting 2½ tons per hr. at high temperature for thin-section castings. The water jackets were cast with vertical corrugations in the face, which were filled with ganister. The cupola operated with half the usual patching and, although the water cost largely offset the savings, the freedom from shutdowns justified the adoption of water cooling. The success with this unit led to the installation of water cooling on two 60-in. cupolas. The tanks are set just above the tuyeres, and give as much as two years of service. Water cooling of these units has been in operation for over four years and is considered an unqualified success. Water requirements average 60 gal. per min., leaving the cooling system at 160 to 175° F. Minor tank leaks are repaired by peening and welding but if a leak is serious the tank is replaced. Coke consumption is reported unchanged.

(Continued on p. 918)

*By W. H. Bamford, British Cast Iron Research Assoc., *Journal of Research and Development*, Vol. 3, August 1949, p. 41.

Cupola Practice

(Continued from p. 916)

In order to reduce the incidence of failure in water-cooled slag holes a tank made with a keyhole opening has been used, the lower portion being filled with ganister.

The 30-in. cupola mentioned has now been water cooled to 63 in. above the tuyeres with a lining of stabilized dolomite; however, the experience with this installation is not sufficient to permit any definite conclusions to be drawn.

Oxygen Enrichment in the Cupola* — The possible effect of oxygen enrichment on the thermal efficiency of metallurgical processes is to a considerable extent determined by the degree of recuperation or regeneration involved. Since the recuperation in most cupolas is limited to the absorption of some of the heat in the products of combustion by the in-going charge, oxygen enrichment results in a higher rate of output and higher metal temperature from any existing unit.

Curves are presented showing the theoretical possibilities of oxygen enrichment in terms of fuel consumption, for different temperatures of exit gases. It appears that even slight enrichment may be distinctly worthwhile at high exit-gas temperatures but would be of little value if exit temperatures were low. If oxygen is expensive, as in Great Britain, the application would require that enrichment be kept low to obtain maximum benefit at minimum cost.

In actual cupola operation the effect of oxygen enrichment, assuming a given rate of fuel consumption, is to reduce the total blast rate, to localize the combustion zone, and to reduce the volume of hot gases. The net effect is faster melting, faster charging and better thermal efficiency. The higher temperature resulting from oxygen enrichment tends toward higher silicon, lower sulphur and increased flexibility of operation. Economically, the use of oxygen is seldom justified except for temporarily increased output.

(Continued on p. 920)

*By W. C. Newell, British Cast Iron Research Assoc., *Journal of Research and Development*, Vol. 3, October 1949, p. 103; and E. C. Evans, p. 109.

ELECTROMET Data Sheet

A Digest of the Production, Properties, and Uses of Steels and Other Metals

Published by Electro Metallurgical Division, Union Carbide and Carbon Corporation, 30 East 42nd Street, New York 17, N. Y. • In Canada: Electro Metallurgical Company of Canada, Limited, Welland, Ontario

MANGANESE . . .
Deoxidizer and Toughener for Steel

Manganese is one of the most important alloys used in making steel. It is practically indispensable as a deoxidizer and cleanser for improving the hot-working properties of steels. When used as an alloying element, it makes steel stronger and tougher and it is therefore an important constituent of many structural and engineering steels.

Deoxidizes and Cleans Steel

The effectiveness of manganese in deoxidizing steel was first recognized in 1856, when it was used in the Bessemer process of steelmaking to counteract the bad effects of sulphur; in fact, manganese made this process a commercial success. Today, manganese is used as a deoxidizer and cleanser in the production of nearly all grades of open-hearth and electric-furnace steel, as well as high-grade cast iron.

Research work carried out recently in ELECTROMET's laboratories at Niagara Falls, New York, has provided new and important information on the value of manganese as a deoxidizer. This work shows that manganese is a more effective deoxidizer than has been previously realized; and that a combination alloy of silicon and manganese is a much stronger deoxidizer than either silicon or manganese by itself. Complete information is given in a report entitled "Solubility of Oxygen in Liquid Iron Containing Silicon and Manganese." If you would like a copy of this report, free of charge, write to the address above.

Improves Hot-Working Properties

By combining readily with sulphur, manganese performs another valuable job. it removes the principal cause of hot-shortness or brittleness—thereby giving steel better rolling and forging properties. In this reaction, the manganese combines with the sulphur to form manganese sulphide, as follows:

$$Mn + FeS = MnS + Fe$$

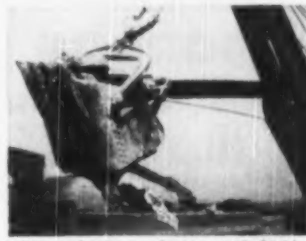
The manganese sulphide remaining in the steel is a less harmful type of inclusion than the iron sulphide would be, the hot-working properties of the steel are improved.

The weakening and embrittling tendencies of sulphur in cast iron can also be counteracted by the addition of manganese to the cupola charge.

Increases Strength, Toughness, and Wear-Resistance

When used as an alloying element in steel, manganese produces a steel with greater strength and toughness, and there is no serious loss of ductility. Additions of about 13 per cent manganese produce the well-known Hadfield manganese steel. High-manganese steels have exceptional resistance to wear; and consequently they have many applications in engineering jobs. Instead of wearing away quickly under conditions combining severe pressure, shock, and abrasion, these steels actually become harder through use. Thus, they last longer.

Because of the tendency of high-manganese steels to work-harden, they serve industry in important and varied applications. Manganese steel castings, for example, are used for railroad frogs and crossings, rock-crusher parts, steam-shovel dipper teeth, and dredge-bucket lips. The chief applications of manganese steel are in rails used for special service, and light forgings subjected to heavy wear.



Dipper bucket teeth, cast of Hadfield manganese steel, actually increase in hardness under abrasive wear from gravel and rock in construction work — thus last many times longer than those of ordinary steel.

Available Alloys

Manganese is produced by ELECTROMET in forms suitable for every use of the iron, steel, and non-ferrous metal industry. The products listed below are available from ELECTROMET plants or warehouses. For a complete description of these alloys, write for a copy of the 100-page booklet, "ELECTROMET Ferro-Alloys and Metals."

The terms "EM" and "Electromet" are registered trade-marks of Union Carbide and Carbon Corporation.

Alloys of Manganese and Their Uses

Standard Ferromanganese	The product most commonly used for adding manganese to steel for the purpose of alloying or deoxidizing and cleansing.
Low-Carbon Ferromanganese	For adding manganese to steels having a low carbon content, such as stainless steels of the 18 per cent chromium, 8 per cent nickel type.
Medium-Carbon Ferromanganese	Commonly used for making manganese steel containing 1.50 to 2.00 per cent manganese, and in the production of Hadfield manganese steel.
Low-Iron Ferromanganese	For applications in the nickel, aluminum, and copper industries where a low-iron alloy is required.
Silicomanganese	Used by the steel industry as a furnace block; as a deoxidizer; and also for manganese additions, particularly in the production of engineering steels containing 0.10 to 0.50 per cent carbon.
Ferromanganese-Silicon Mix	Used as a ladle inoculant for cast iron.
Manganese Metal	Used as a deoxidizing agent and alloying element in the production of non-ferrous alloys.
"EM" Silicomanganese Briquets	For adding manganese (with silicon) to cast iron in the cupola.
"EM" Ferromanganese Briquets	For adding manganese (without silicon) to cast iron in the cupola.

Cupola Practice

(Starts on p. 916)

Results of tests at Allis-Chalmers and at Armour Institute are discussed in some detail. These experiments have already been reported in the American technical press (*Iron Age*, April 22, 1948, and *Foundry*, June 1948). However, it may be noted that although the output of the cupolas involved increased greatly with oxygen enrichment the deterioration of refractories was likewise accelerated. The published work on oxygen enrichment in the cupola indicates that usually neither charging nor casting facilities are adequate to handle the greatly increased output effectively.

Since in large foundries the possibility exists that an oxygen plant might be justified the author discusses the various methods of producing oxygen in large quantities —including the high, medium and low-pressure systems for high-purity and low-purity gas. For most foundries, it will be cheaper to purchase oxygen than to manufacture it.

Current Hot Blast Cupola Practice* —Hot blast operation of cupolas appears to be virtually nonexistent in Great Britain; the discussion is concerned with practice in the United States and Continental Europe.

Hot blast cupola operation may be employed to obtain higher metal temperature, lower coke consumption, or some intermediate combination of the two advantages. Melting rate is likewise increased and the charge moves more smoothly in the melting zone. Losses of iron, silicon and manganese are lower and sulphur content of the metal may be lower.

Moderate blast preheat is obtained in several designs by absorbing heat directly from the cupola itself by replacing part of the lining with cast-iron pipes through which the blast passes. Higher blast temperatures are obtained with the Whiting system in which an external, separately fired preheater is used. A similar system (Schaffhausen) in Germany employs a counterflow preheater with heat resisting tubes to obtain a hot blast at 750 to 930° F. *(Turn to p. 922)*

*By W. J. Driscoll, British Cast Iron Research Assoc., *Journal of Research and Development*, Vol. 3, December 1949, p. 201.

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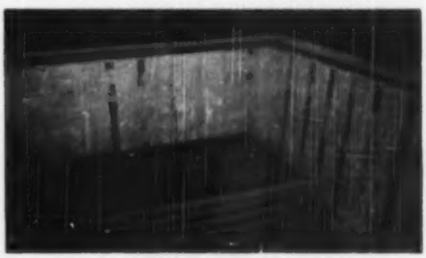

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Cupola Practice

(Starts p. 916) Several installations in Germany and the United States use the incompletely burned products of combustion to fire preheaters that supply hot blast. The systems are recuperative and some trouble is experienced with accumulations of dust which must be blown out periodically.

Although there are distinct metallurgical advantages to hot blast operation of cupolas, the high capital investment and maintenance problems are deterrents to the adoption of this system of operation in Great Britain. The author feels that hot blast operation was developed extensively on the Continent to compensate for poor coke, while in British foundry practice the capital investment is not likely to be undertaken as long as high-quality coke is available.

S. Feigenbaum

Cast Al-Cu-Si Alloys*

For a long time before the last war American foundries shunned aluminum-zinc alloys, while the Germans disliked the aluminum-copper alloys. Thus, on the European continent, the 8% Cu alloy and its derivatives were called "the American alloys" while the 12% Zn plus 3% Cu alloy was called "the German alloy". Only recently (during the war) were the Al-Cu-Si alloys, which are in general use in the States, investigated in Germany.

The research covered forty-four compositions. Eighteen of these were made of the purest aluminum obtainable (99.9% plus) and only copper and silicon were added; others carried various amounts of magnesium and manganese, added on purpose, and iron or titanium, present incidentally. This was done in order to see whether the alloys could be prepared from scrap aluminum — as if it were not known in Germany that the U. S. has many

(Continued on p. 924)

*Abstract from "Aluminum Foundry Alloys Based on the Al-Cu-Si Ternary System", by F. Bollenrath and H. Groeber, *Metallforschung*, Vol. 1, 1946, p. 111-116.

Cast Al-Cu-Si Alloys

(Continued from p. 922)

plants which prepare secondary aluminum alloys by the ton.

The authors made substantial heats of 15-kg. size, cast into German standard types of sand and chill molds. The treatment was 4 hr. at 930° F., water quenched and reheated to 320° F. for various periods from 6 to 50 hr.

The research was done with high precision and the brief paper abounds in diagrams. There was only one trouble — the melts were not degassed. The most important component — hydrogen — was neither evacuated nor evaluated. In this reviewer's experience, gas is a most prolific source of aluminum castings of poor mechanical characteristics.

The best of the pure alloys contained about 5% Si and 2% Cu and showed, as sand cast, a yield strength of 9000 to 10,000 psi. (0.2% in 10 cm.), tensile strength of 21,000 to 23,000 psi., and 5 to 6% elongation. As heat treated: 23,000 psi., 34,000 psi., and 2%.

Of the binary alloys, one with 7.6% Cu — very close to the so-called American composition — showed 10,000 psi. yield and 15,000 psi. tensile strength with 1.8% elongation, as sand cast, and 20,000 psi., 21,000 psi., and 0.5%, as heat treated. It is, however, well known that our foundries used to turn out castings with 8% Cu made of low-grade aluminum with a tensile strength of at least 17,000 and frequently 19,000 psi. as sand cast. This reviewer never failed to obtain 35,000 psi. tensile with 2% elongation in the 8% Cu alloy made with 99.7% Al, and heat treated, but of course hydrogen was eliminated to a very great extent and the density brought to a uniform level.

Of the more complex alloys, the authors obtained best results with 3% Si, 3% Cu, 0.3% Mg, 0.8% Mn and 0.5% Fe. They got 21,000 and 26,000 psi. for the yield and tensile strengths, as sand cast, and 37,000, 40,000, and 0.5%, as heat treated.

Perhaps the most valuable results of this investigation are the diagrams showing age hardening at 320° F. Hardness depends only slightly on the hydrogen content, which, as noted above, was not evaluated. M. G. C.

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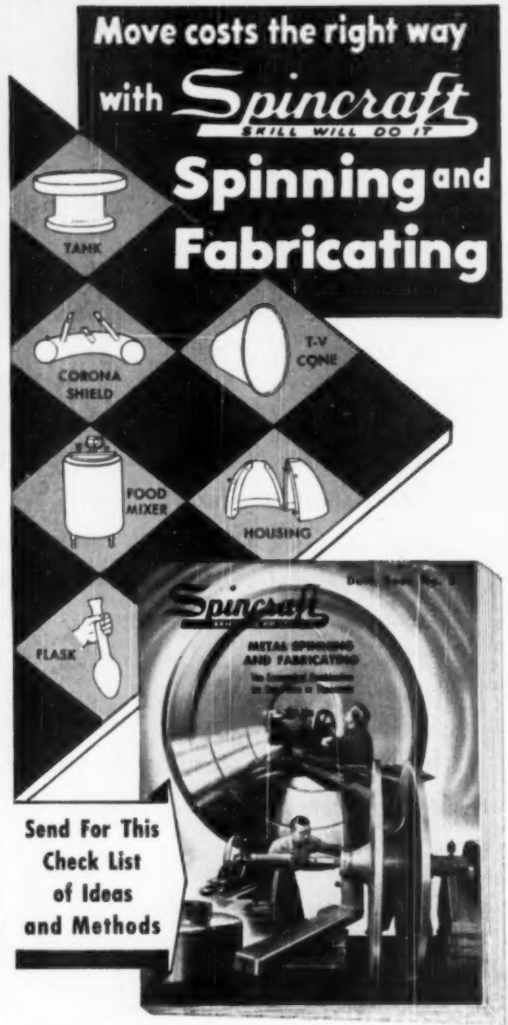

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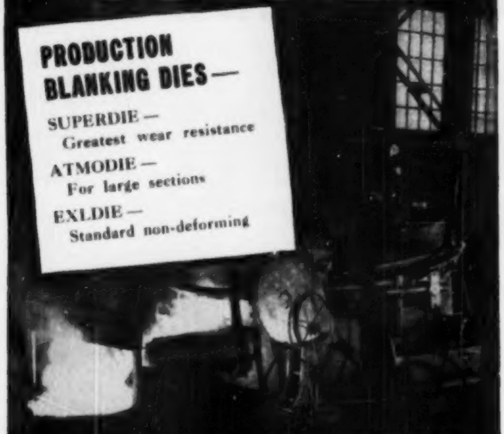

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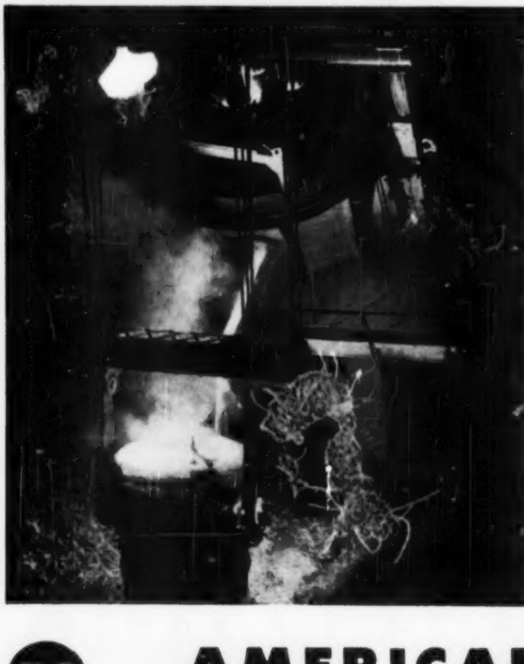

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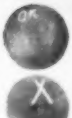

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Volume 58; July 1950 to December 1950

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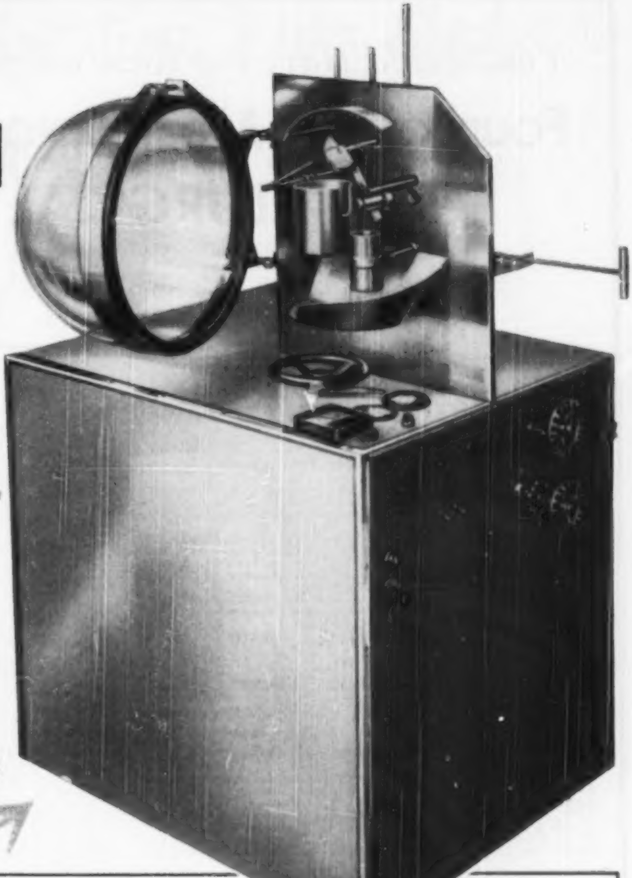
(a) Abstract; *(c)* Correspondence; *(cp)* Critical Points; *(d)* Data Sheet.

NOW

You can afford a High Vacuum Furnace



This ONE Versatile Unit lets you melt, pour, heat treat, degas

At last there is now available a single furnace that does away with the need to purchase equipment for each phase of your high-vacuum, high-temperature work. Because of its modest price, it will fall within the budget of most laboratories.

With this new furnace you can melt and solidify — melt and pour — add to the melt — stir — look into the hot zone — measure hot zone temperatures — introduce controlled atmospheres — degas — heat treat. It's a complete, versatile unit, capable of handling the widest variety of metallurgical research work. Write today.

FEATURES—

- Ultimate vacuum of less than 5×10^{-5} mm. Hg.
- Working temperatures up to 2000° C.
- Temperature controllable within ± 5° C.
- Hot zone reaches temperature within one minute.
- No refractories used in hot zone.
- 4" purifying type diffusion pump insures high capacity for out-gassing.
- Utilizes single turn low voltage resistance element of either tungsten or molybdenum 8" x 2½" dia.
- Constant temperature zone 6" x 2½" dia.
- Power supplied directly from mains to specially-designed variable auto transformer which is an integral part of unit.
- Either manual or automatic temperature control or both.
- Thermocouple vacuum gage is standard equipment. Other gages are available.
- Furnished complete with vacuum system, controls and gages including ammeter, volt-meter and temperature indicator.

INDUSTRIAL RESEARCH · PROCESS DEVELOPMENT
HIGH VACUUM ENGINEERING AND EQUIPMENT

METALLURGY · DEHYDRATION · DISTILLATION
COATING · APPLIED PHYSICS

National Research Corporation

Seventy Memorial Drive, Cambridge, Massachusetts

In the United Kingdom: BRITISH-AMERICAN RESEARCH, LTD., London S.W. 7 — Wishaw, Lanarkshire

"This is the first time I ever *liked* listening to Crosby!"

says HOPE

HOPE:
For years, I've always stuck cotton in my ears whenever the Old Groaner opened his mouth. But now he's got something that sounds good. Really good. Let's hear it, kid.

CROSBY:
Thank you Mr. Hope. You are kind, very kind. Ladies and gentlemen, this isn't a song. It's just a suggestion. This year, let's *all* give U. S. Savings Bonds for Christmas presents. Tell 'em about those bonds, Chisel Nose.

HOPE:
Gladly. It's all very simple—even Crosby understands how they work. In just ten years, they pay $4 for every $3 they cost. And they're appropriate for *everybody* on your Christmas list—young people, middle-aged people, and people as old as Crosby. Am I right, Bing?

CROSBY:
For once in his life the old Scene-Stealer *is* right. But seriously, folks, nothing makes a more welcome, more sensible present than U. S. Savings Bonds. And you can buy 'em in any bank or post office. So—

HOPE:
So why not give the very finest gift in America—U. S. Savings Bonds!

Give the finest gift of all... U.S. Savings Bonds

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METAL PROGRESS

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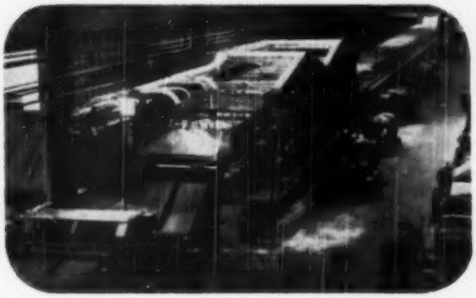
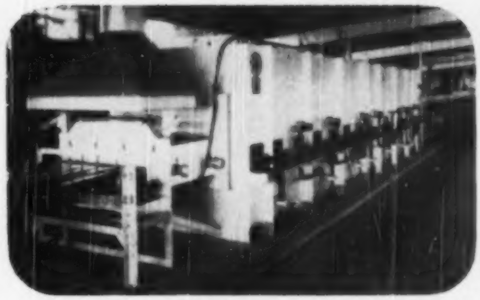
TOWER PRESS
CLEVELAND



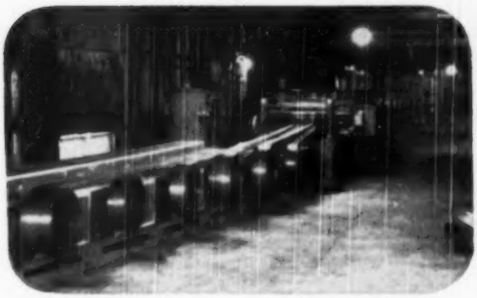
Steel strip in single or multiple strands up to a total width of 54" may be bright annealed or normalized, continuously, in this EF gas fired radiant tube installation. Capacity 7200 lbs. per hour.



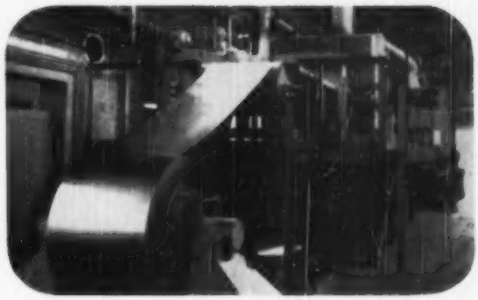
An EF electrically heated special atmosphere installation bright annealing six parallel strands of cold rolled steel strip, continuously. Handles single or multiple strands up to a total width of 30".

SOME TYPICAL EF INSTALLATIONS

For Processing Strip



Another EF gas fired radiant tube, continuous furnace for bright annealing or normalizing cold rolled strip steel. Has preheater or burn-off chamber and handles 2000 lbs. strip per hour.

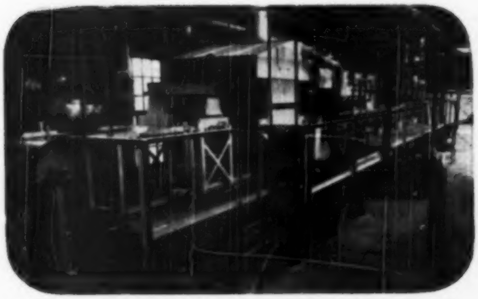


An EF special atmosphere furnace with flame preheating burn-off or oxidizing section, and controlled heating and cooling zones for producing various surface conditions on strip steel.

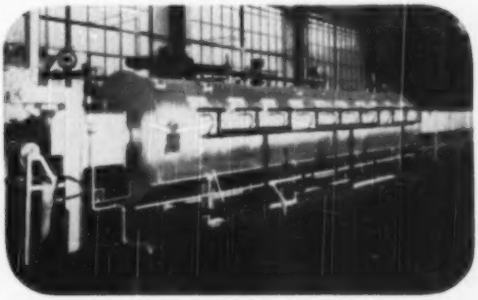
Designed and Built by

The Electric Furnace Co., Salem, Ohio

Gas Fired, Oil Fired and Electric Furnaces — For Any Process, Product or Production



This EF combination fuel fired and electrically heated strip processing unit provides extreme flexibility in heating, soaking and controlled cooling cycles for treating various grades of strip.



Stainless steel strip is bright or process annealed continuously in this EF gas fired special atmosphere tube muffle type furnace. It also handles other strip requiring lower temperatures.

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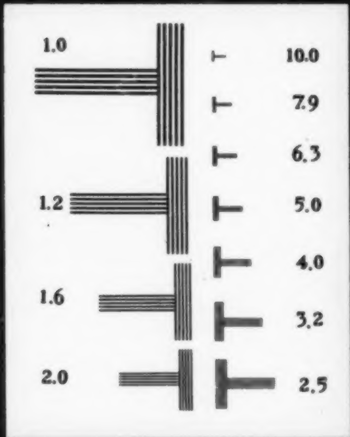
RESOLUTION CHART



100 MILLIMETERS

INSTRUCTIONS Resolution is expressed in terms of the lines per millimeter recorded by a particular film under specified conditions. Numerals in chart indicate the number of lines per millimeter in adjacent "T-shaped" groupings.

In microfilming, it is necessary to determine the reduction ratio and multiply the number of lines in the chart by this value to find the number of lines recorded by the film. As an aid in determining the reduction ratio, the line above is 100 millimeters in length. Measuring this line in the film image and dividing the length into 100 gives the reduction ratio. Example: the line is 20 mm. long in the film image, and 100/20 = 5.

Examine "T-shaped" line groupings in the film with microscope, and note the number adjacent to finest lines recorded sharply and distinctly. Multiply this number by the reduction factor to obtain resolving power in lines per millimeter. Example: 7.9 group of lines is clearly recorded while lines in the 10.0 group are not distinctly separated. Reduction ratio is 5, and 7.9 x 5 = 39.5 lines per millimeter recorded satisfactorily. 10.0 x 5 = 50 lines per millimeter which are not recorded satisfactorily. Under the particular conditions, maximum resolution is between 39.5 and 50 lines per millimeter.

Resolution, as measured on the film, is a test of the entire photographic system, including lens, exposure, processing, and other factors. These rarely utilize maximum resolution of the film. Vibrations during exposure, lack of critical focus, and exposures yielding very dense negatives are to be avoided.